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DIPLOMOVÁ PRÁCE

Modernizace zkušebny – návrh pomocné převodovky

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HOSNEDL, S., KRÁTKÝ, J. *Příručka strojního inženýra: obecné strojní části. 1, Spoje, otočná uložení, hřídelové spojky, akumulátory mechanické energie.* Praha: **Computer Press, 1999**

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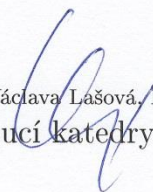
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Prohlašuji, že jsem tuto diplomovou práci vypracoval samostatně, s použitím odborné literatury a pramenů, uvedených v seznamu, který je součástí této diplomové práce.

V Plzni dne:

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CELKEM	264	TEXTOVÁ ČÁST	50	GRAFICKÁ ČÁST	2
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STRUČNÝ POPIS (MAX 10 ŘÁDEK) ZAMĚŘENÍ, TÉMA, CÍL POZNATKY A PŘÍNOSY	<p>Téma této práce je návrh pomocné převodovky. Tato převodovka je určena pro zkušebnu ve firmě Wikov Gear s.r.o. Hlavním cílem je konstrukční návrh převodové skříně s potřebnými převody. V práci jsou uvedeny základní výpočty, grafy, modální analýza převodové skříně pomocí MKP a výkresy.</p>
KLÍČOVÁ SLOVA ZPRAVIDLA JEDNOSLOVNÉ POJMY, KTERÉ VYSTIHUJÍ PODSTATU PRÁCE	<p>převodová skříně, ozubené kolo, pastorek, hydrodynamické ložisko, hřídel, asynchronní motor, frekvenční měnič, nalisování, modální analýza, olej, svar, labyrinthové těsnění, šroub, náklady</p>

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BRIEF DESCRIPTION TOPIC, GOAL, RESULTS AND CONTRIBUTIONS	The theme of this work is design of the auxiliary gearbox. This gearbox is for laboratory in company Wikov Gear s.r.o. The main object is engineering design of gearbox with necessary gears. This work contains the main calculations, graphs, modal analyze of gearbox by using Finite Element Method and drawings.
KEY WORDS	gearbox, gear wheel, pinion, hydrodynamic bearings, shaft, asynchronous motor, frequency converter, interference fit, modal analyze, oil, weld, labyrinth seals, screw, costs

Poděkování

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Přehled použitých zkratk a symbolů

RBE2, RBE3, CBEAM, CTETRA(10)		typ segmentů sítě
HMH		Hubert, von Mises, Hencky
CAD		computer-aided design
MKP		metoda konečných prvků

převodový poměr	i	[–]
otáčky	n	[$ot./s$]
síla	F	[N]
kroucí moment	M	[$N \cdot m$]
výkon	P	[W]
hmotnost	m	[kg]
součinitel tření	f	[–]
tlak	p	[Pa]
napětí	σ	[Pa]
bezpečnost	s	[–]
počet zubů	z	[–]
modul ozubení	m	[m]
osová vzdálenost	a	[m]
úhel záběru	α	[°]
sklon šikmého ozubení	β	[°]
průměr	$d; D$	[m]
plocha	S	[m^2]
Youngův modul pružnosti v tahu	E	[Pa]
Poissonovo číslo	ν	[–]
Sommerfeldovo číslo	So	[–]
hustota	ρ	[kg/m^3]
průtok	Q	[l/s]
teplota	t	[°C]

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1 Úvod

Zadavatelem této diplomové práce je firma Wikov Gear s.r.o., která je předním výrobcem převodovek pro těžký průmysl a rychloběžných převodovek. Převodovka je zařízení, které pomocí mechanického převodu transformuje velikost síly, pohyb a polohu dle požadavků. Základním typem je jednostupňová převodovka s vnějším ozubením, která transformuje velikost krouticího momentu a otáček mezi hnacím a hnaným hřídelem. Kinetická vazba mezi ozubenými koly je zajištěna nejčastěji odvalováním jednotlivých ploch boku zubů po evolventní křivce. Výhodou této mechanické vazby je minimální přetvoření mechanické energie v jinou, např. tepelnou, a proto má většina těchto převodů velmi vysokou účinnost. Další výhodou je konstantní převodový poměr, na kterém je závislá změna točivého momentu a otáček mezi vstupním a výstupním členem. Tento převodový poměr je stanoven jako podíl průměrů nebo počtu zubů jednotlivých ozubených kol, kde se nazývá menší ozubené kolo pas-torkem a větší kolem. Pokud je převodový poměr $i > 1$, jedná se o převod do pomala, tzv. reduktor, naopak pokud je převodový poměr $i < 1$, jedná se o převod do rychla, tzv. multipli-kátor.

1.1 Základní dělení převodovek ^{[4]; [5]}

Dělení dle kinetiky pohybu:

- rotační \Leftrightarrow rotační
- rotační \Leftrightarrow lineární
- lineární \Leftrightarrow lineární
- rotační \Leftrightarrow periodický

Dělení podle funkce:

- lineární
- nelineární

Dělení dle přenosu energie:

- jednosměrné
- obousměrné
- samosvorné

Dělení dle provedení ozubených kol:

- vnitřní ozubení
- vnější ozubení (čelní)
- s přímými, šikmými nebo šípovitými zuby
- s kuželovým soukolím
- se šnekovým převodem

1.2 O firmě Wikov Gear s.r.o. ^[3]

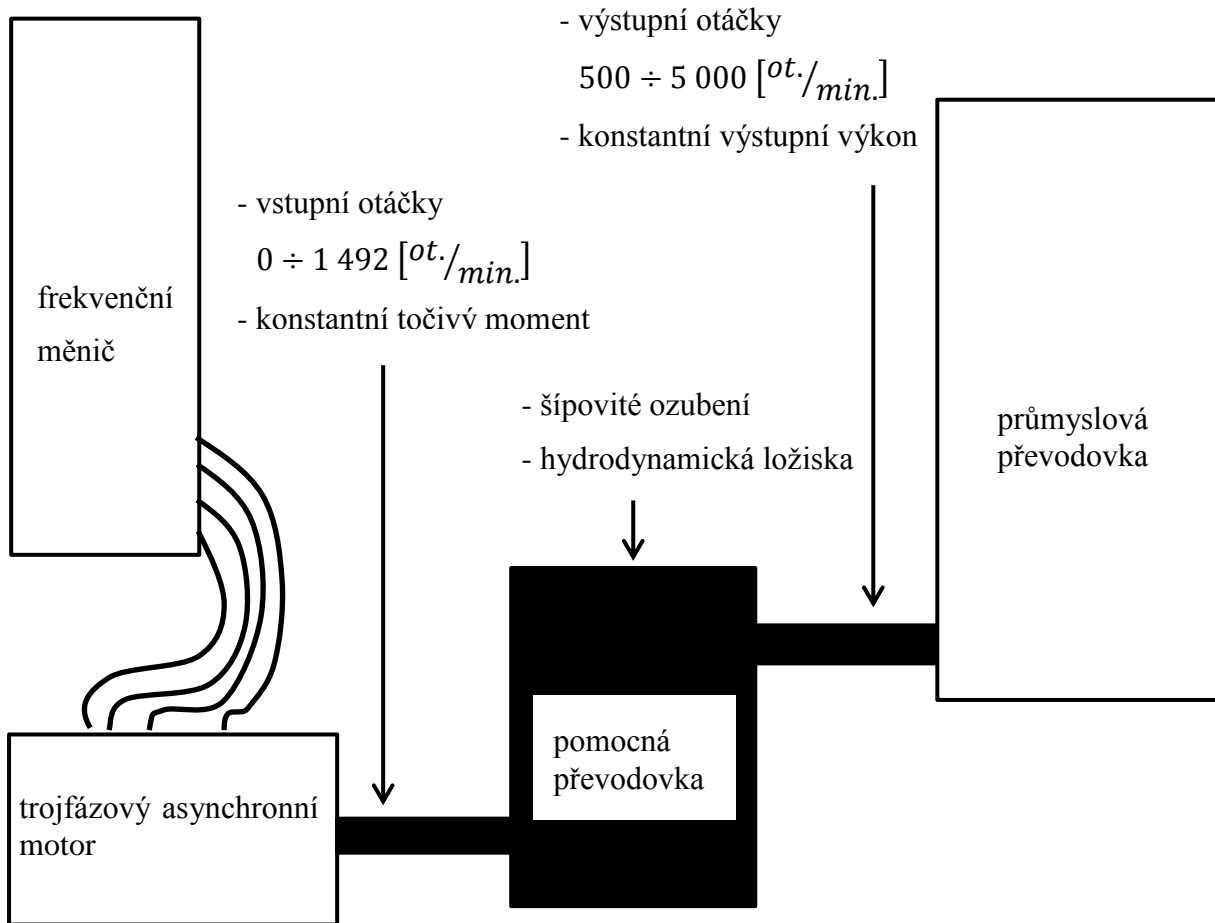
Společnost Wikov je aktivní v mechanickém strojírenství více než 125 let. Přes 80 let je tradičním výrobcem ozubených kol a mechanických převodovek. Název této firmy pochází ze jmen zakladatelů Wichterle-Kovářík, kde byl František Wichterle dědečkem známého českého vynálezce kontaktních čoček profesora Otty Wichterleho. Jedná se tedy o českou firmu. Firma Wikov se dělí na několik společností, mezi které patří právě Wikov Gear s.r.o.

Výrobní závod Wikov Gear s.r.o. se specializuje na:

- design a výrobu převodovek pro:
 - tepelné elektrárny
 - povrchové doly
 - cementárny a zpracování minerálů
 - průmysl těžby ropy a plynu
 - cukrovary
 - chemický průmysl
- design a výrobu rychloběžných převodovek
- výrobu kuželových kol s ozubením Klingelnberg do průměru 1 150 [mm] (lapované a HPG)
- výrobu profilově broušených ozubených kol s přímým vnitřním a vnějším ozubením do průměru 2 500 [mm]
- výrobu frézovaných ozubených dílů do průměru 3 500 [mm]

2 Zadání

Cílem této diplomové práce je navrhnout jednostupňovou pomocnou převodovku pro testování průmyslových převodovek, které firma Wikov Gear s.r.o. vyrábí. Hlavním požadavkem na tuto pomocnou převodovku je pokrytí výstupních otáček v rozmezí $500 \div 5\,000$ [ot./min.] při použití jedné převodové skříně. Toho má být docíleno výměnou jednotlivých soukolí za jiné s potřebným převodovým poměrem, který je potřeba na testování průmyslové převodovky. K testování firma využívá elektrický trojfázový asynchronní motor o výkonu 710 [kW] se jmenovitým počtem otáček $n = 1\,492$ [ot./min.]. Regulace otáček tohoto motoru je zajištěna frekvenčním měničem. Pomocná převodovka má obsahovat ozubená kola s dvojitě šikmými zuby, jejichž vhodnost je shrnuta v tab. 1. Uložení hnaného a hnacího hřídele má být zajištěno pouze pomocí hydrodynamických ložisek, díky kterým má být zamezeno velkým ztrátám výkonu. Pomocná převodovka má být schopna přenášet nejvyšší možný výkon s rozumným počtem výměnných převodů. Celé schéma zkušebny s potřebným zařízením je zobrazeno na obr. 1.



obr. 1 schéma zkušebny s pomocnou převodovkou

Výhody:	Nevýhody:
vysoká mechanická účinnost	složitější a dražší výroba
přesné dodržení převodového poměru	nároky na přesnost a tuhost uložení
schopnost přenosu velikých výkonů	hluk a chvění (u většiny těchto převodů)
schopnost dosažení relativně vysokých převodových poměrů	tuhá vazba neumožňuje tlumení rázů a dynamického zatížení
dobrá spolehlivost a životnost	malé osové vzdálenosti
relativně malé rozměry	
malá náročnost na údržbu	
krátkodobá přetížitelnost	

tab. 1 výhody a nevýhody šikmého ozubení ^[5]

2.1 Specifikace frekvenčního měniče a motoru

Aby bylo možné regulovat otáčky trojfázového asynchronního motoru v určitém rozmezí otáček při konstantním krouticím momentu, je zapotřebí frekvenční měnič. U frekvenčních měničů lze regulovat proud nebo napětí a frekvenci, pomocí které je motor poháněn. Vlivem regulace proudu je na motoru regulován krouticí moment a vlivem regulace napětí a frekvence jsou na motoru regulovány otáčky. Vlivem použití frekvenčního měniče dochází ke ztrátě celkového výkonu motoru o cca 10 [kW]. Protože jsou na motoru regulovány otáčky a tedy i napětí a frekvence, teče přívodní kabeláží do motoru velký proud, proto je kabeláž poměrně robustní. Na motoru tedy lze regulovat otáčky při konstantním krouticím momentu, který nesmí být vyšší než jmenovitý moment motoru, jinak by došlo k jeho přetížení. Vlivem tohoto faktu dochází ke změně vstupního výkonu. Protože požadavkem pomocné převodovky je konstantní výstupní výkon, dojde k poměrně značnému poklesu výkonu oproti výkonu udávaným výrobcem motoru.

Parametry trojfázového asynchronního motoru:

značka a typ..... CANTONI Sh 450 H4Bs
výkon 710 [kW]
otáčky..... 1 492 [ot./min.]
krouticí moment..... 4 544 [N · m]
hmotnost..... 4 000 [kg]
rozměry..... 2 090 x 1 356 x 940 [mm]
počet pólů..... 4 [–]



obr. 2 trojfázový asynchronní motor

Parametry frekvenčního měniče pro motor:

značka a typ..... Danfoss FC 302 P 630
výkon 630 [kW]
hmotnost..... 1 004 [kg]
rozměry..... 1 400 x 2 280 x 670 [mm]
krytí..... IP21



obr. 3 frekvenční měnič^[6]

3 Návrh převodů

Prvním krokem výpočtu bylo stanovení rozdílu vstupních otáček. Tím je umožněno stanovit orientační počet převodů, který pokryje výstupní pole požadovaných otáček. Z těchto parametrů je možné stanovit výstupní výkon z pomocné převodovky, která pokryje požadované spektrum výstupních otáček. Na základě zkušeností konstruktérů z firmy Wikov Gear s.r.o. je účinnost převodovky s šikmým ozubením a použitím hydrodynamických ložisek 98 [%]. Ve výpočtech jsou značeny vstupní členy s indexem 1. Výstupní členy jsou značeny indexem 2.

$$\mu = 98 [\%] = 0,98 [-] \dots\dots\dots \text{účinnost převodovky}$$

$$P = M_k \cdot \omega \dots\dots\dots \text{výkon pro točivé stroje}$$

$$\omega = 2 \cdot \pi \cdot n \dots\dots\dots \text{úhlová rychlost}$$

⇓

$$P = M_k \cdot 2 \cdot \pi \cdot n$$

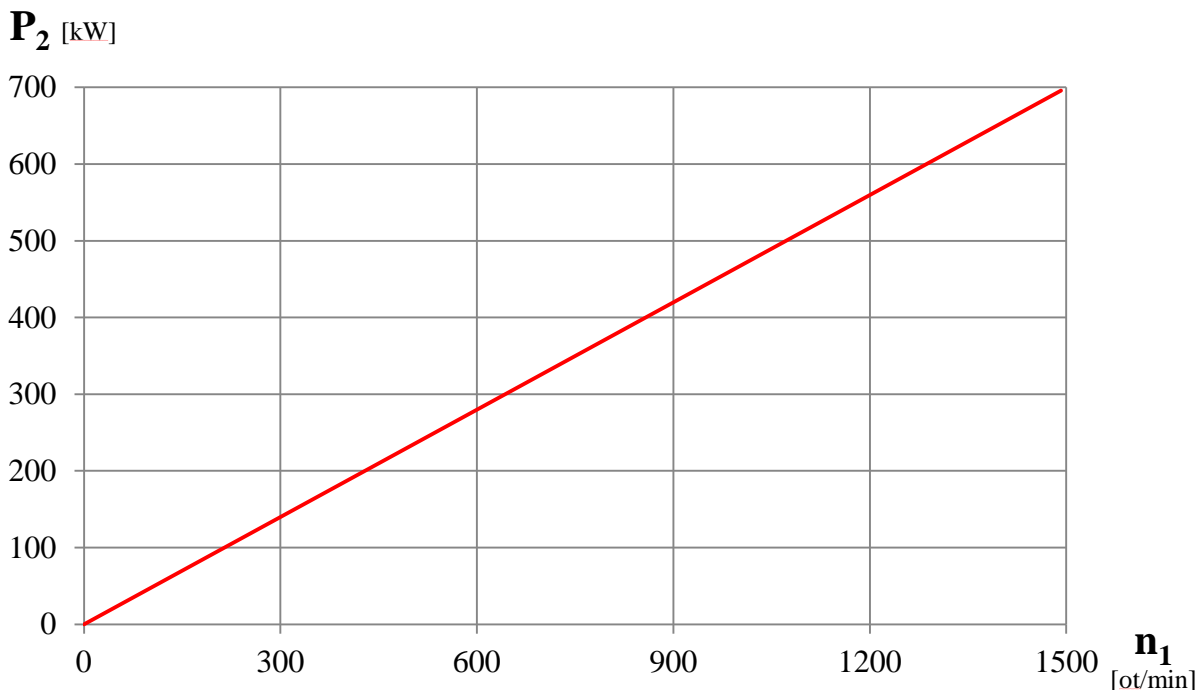
$$P_2 = P_1 \cdot \mu \dots\dots\dots \text{výstupní výkon}$$

⇓

$$n_{1 \min.} = \frac{P_2}{M_k \cdot 2 \cdot \pi} \cdot \frac{60}{\mu} = \frac{500\,000}{4\,544 \cdot \pi} \cdot \frac{30}{0,98} = 1\,073 \left[\frac{\text{ot.}}{\text{min.}} \right] \dots\dots\dots$$

..... stanovené minimální pracovní otáčky asynchronního motoru

vstupní otáčky v závislosti na výstupním výkonu při konstantním momentu



graf 1 závislost výstupního výkonu na otáčkách asynchronního motoru

Z grafu „graf 1“ je patrné, že výstupní výkon bude proměnlivý v závislosti na otáčkách asynchronního motoru. Jelikož v zadání byl stanoven výstupní výkon konstantní při celém spektru zadaných otáček, stanovil jsem tento konstantní výstupní výkon na $P_2 = 500 [kW]$. Tento výstupní výkon byl prodiskutován a odsouhlasen se zadavatelem této diplomové práce. Pokud by mohl být výstupní výkon proměnlivý, pohyboval by se v rozmezí $500 \div 696 [kW]$ ve stanovených pracovních otáčkách asynchronního motoru tj. $1\ 073 \div 1\ 492 [ot./min.]$.

$$n_{1\text{ rozdíl}} = n_{1\text{ max.}} - n_{1\text{ min.}} = 1\ 492 - 1\ 073 = 419 [ot./min.]$$

.....stanovené rozmezí pracovních otáček asynchronního motoru

3.1 Stanovení potřebných převodů

$$i_{12}^* = \frac{n_{1\text{ max.}}}{n_{2\text{ max.}}} = \frac{1\ 492}{5\ 000} = 0,2984 [-]$$

$$n_{2\text{ min.}} = \frac{n_{1\text{ min.}}}{i_{12}^*} = \frac{1\ 073}{0,2984} = 3\ 596 \left[\frac{ot.}{min.} \right]$$

Nejdříve byl spočítán převodový poměr pro maximální vstupní a výstupní otáčky. Z tohoto převodového poměru je možné zpětně dopočítat minimální výstupní otáčky, které nastanou při minimálních vstupních otáčkách.

Postup byl analogicky opakován v programu Excel, dokud nebylo dosaženo na výstupním členu požadovaných $500 [ot./min.]$. Na základě tohoto výpočtu bylo stanoveno 7 potřebných převodů, tj. 7 výměnných soukolí. Každý z těchto potřebných převodů je poměrně finančně náročný na výrobu a představuje výrobu dvou hřídelů a dvou ozubených kol, proto jsem se snažil toto číslo dále zredukovat bez dalšího poklesu výstupního výkonu. Jediným řešením, které připadalo v úvahu, bylo otočení celé převodové skříně o $180 [^\circ]$, tedy záměnu vstupního hřídele za výstupní a výstupní hřídel za vstupní. Tato skutečnost stanovila potřebný počet převodů na 4 výměnné převody, které mají v tab. 2 stanoveny teoretické převodové poměry. Výhodou je zároveň minimalizace výměny převodů, které pokryjí zadané spektrum výsledných otáček.

$$i_{21} = \frac{1}{i_{12}} \text{.....převodový poměr v závislosti na změně vstupního členu za výstupní}$$

i_{21}^*	i_{43}^*	i_{65}^*	i_{87}^*
3,3512	2,4095	1,7326	1,2460

tab. 2 teoretické převodové poměry pomocné převodovky

Dále následuje návrh počtu zubů pro každý teoretický převodový poměr a stanovení skutečného převodového poměru. Návrh počtu zubů byl optimalizován pomocí programu Excel tak, aby všechny jednotlivé převody měly přibližně shodnou teoretickou osovou vzdálenost a každý z převodů měl na jednom ozubeném kole sudý počet zubů a na druhém kole lichý počet zubů, což by mělo zlepšit celkový chod převodu. Všechna ozubená kola byla navržena pomocí specializovaného programu na ozubení programem KISSOFT. Vstupní data pro návrh jsou shrnuta v kapitole 3.4. Výsledné reporty o parametrech ozubených kol jsou v „Příloha 1“ diplomové práce.

$$i_{12} = \frac{z_2}{z_1} \dots \dots \dots \text{skutečný převodový poměr}$$

Výpočet teoretické osové vzdálenosti pro vnější válcové soukolí s šikmými zuby:

$$d_1 = \frac{m \cdot z_1}{\cos \beta} \dots \dots \dots \text{průměr roztečné kružnice prvního ozubeného kola}$$

$$a_{12 \text{ teor.}} = 0,5 \cdot (d_1 + d_2) \dots \dots \dots \text{teoretická osová vzdálenost prvního soukolí}$$

$$z \dots \dots \dots \text{počet zubů na ozubeném kole}$$

$$\beta \dots \dots \dots \text{úhel sklonu šroubovice šikmého ozubení}$$

Úhel sklonu β pro šípovité ozubení mi bylo doporučeno konstruktéry z firmy Wikov Gear s.r.o. na minimálně 25 [°]. Pro výpočet všech soukolí jsem stanovil jednotný úhel sklonu $\beta = 25$ [°]. Základní rozměry jednotlivých soukolí jsou shrnuty v tab. 4.

Hrubý návrh modulů jednotlivých soukolí dle Bachova vzorce:

$$m^* = 7,5 (8,6) * \sqrt[3]{\frac{M_k * \cos \beta}{c * \psi * z_1}} [mm]$$

$$\psi = 8 \div 12 [-] \dots \dots \dots \text{poměrná šířka ozubeného kola}$$

$$c = 10 \div 15 [MPa] \dots \dots \dots \text{materiálová konstanta}$$

pro šikmé ozubení tj. $\beta \neq 0$ platí koeficient 7,5

pro přímé ozubení tj. $\beta = 0$ platí koeficient 8,6

Za krouticí moment M_k je potřeba dosadit v [N · m], protože koeficient 7,5 nebo 8,6 zajišťuje také přepočtení na [N · mm].

Výsledné orientační moduly pro jednotlivá soukolí jsou shrnuty v tab. 3. Vzhledem k výrobě ozubeného kola jsem stanovil skutečný modul ozubení pro všechny soukolí stejný o velikosti $m = 6$ [mm].

m_{12}^*	m_{34}^*	m_{56}^*	m_{78}^*	
6,1971	6,3769	6,6158	6,8523	[mm]

tab. 3 orientační moduly ozubení dle Bacha

$i_{21} / i_{43} / i_{65} / i_{87}$	3,3182	2,3929	1,7143	1,2558	[-]
$z_1 / z_3 / z_5 / z_7$	73	67	60	54	[-]
$z_2 / z_4 / z_6 / z_8$	22	28	35	43	[-]
β	25				[°]
c	10				[MPa]
ψ	10				[-]
m	6				[mm]
$d_1 / d_3 / d_5 / d_7$	483,280	443,558	397,216	357,494	[mm]
$d_2 / d_4 / d_6 / d_8$	145,646	185,367	231,709	284,672	[mm]
$a_{12 \text{ teor.}} / a_{34 \text{ teor.}} / a_{56 \text{ teor.}} / a_{78 \text{ teor.}}$	314,463	314,463	314,463	321,083	[mm]

tab. 4 základní rozměry jednotlivých soukolí

Vlivem potřebné změny převodových poměrů oproti orientačním převodovým poměrům v tab. 2 dojde ke změně výsledných otáček, které se musí přepočítat a jsou uvedeny v kapitole 3.2.

3.2 Parametry navržených převodů

$$M_{k2} = M_{k1} \cdot i \dots\dots\dots \text{výstupní krouticí moment}$$

	i_{12}	i_{34}	i_{56}	i_{78}	
	0,3014	0,4179	0,5833	0,7963	[-]
$n_{2 \max.}$	4 950	3 570	2 557	1 873	[<i>ot./min.</i>]
$n_{2 \min.}$	3 561	2 568	1 840	1 348	[<i>ot./min.</i>]
$n_{1 \max.}$	1 492				[<i>ot./min.</i>]
$n_{1 \min.}$	1 073				[<i>ot./min.</i>]
$M_{2 \min.}$	984	1 365	1 905	2 601	[<i>N · m</i>]
$M_{2 \max.}$	1 369	1 899	2 651	3 618	[<i>N · m</i>]
$M_{1 \min.}$	3 265				[<i>N · m</i>]
$M_{1 \max.}$	4 544				[<i>N · m</i>]

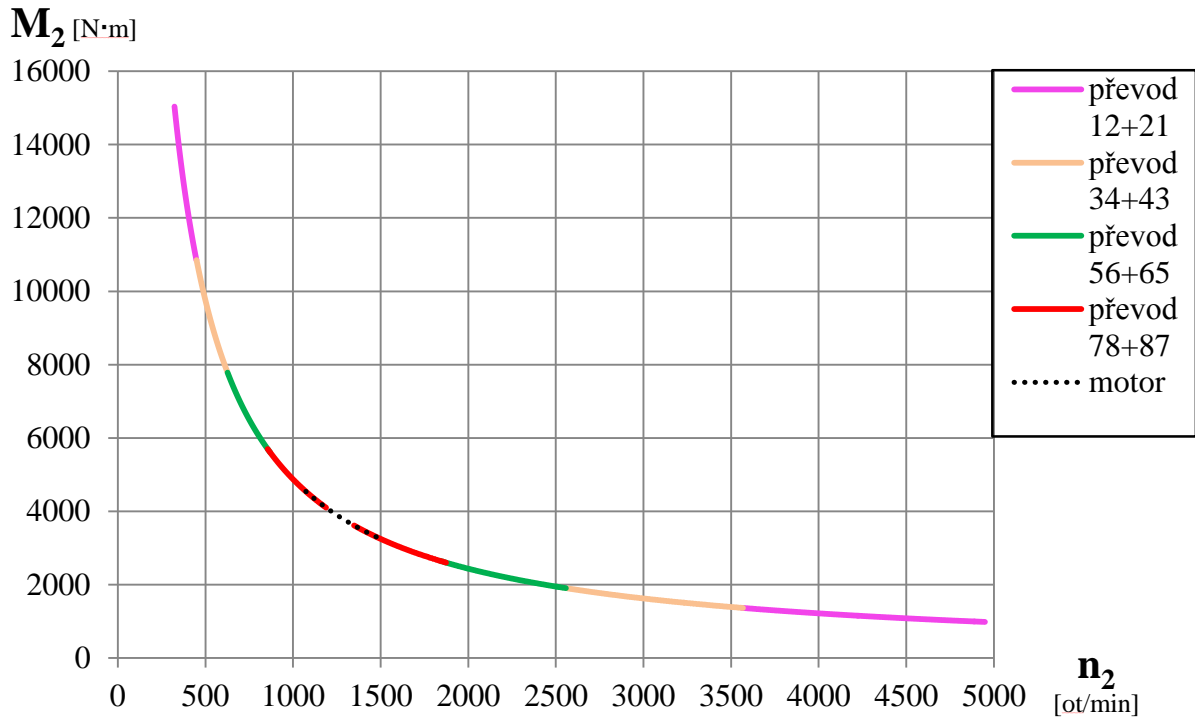
tab. 5 otáčky a krouticí momenty jednotlivých soukolí

	i_{21}	i_{43}	i_{65}	i_{87}	
	3,3182	2,3929	1,7143	1,2558	[-]
$n_{1 \max.}$	449	623	870	1 188	[<i>ot./min.</i>]
$n_{1 \min.}$	324	449	626	855	[<i>ot./min.</i>]
$n_{2 \max.}$	1 492				[<i>ot./min.</i>]
$n_{2 \min.}$	1 073				[<i>ot./min.</i>]
$M_{1 \min.}$	10 851	7 820	5 600	4 101	[<i>N · m</i>]
$M_{1 \max.}$	15 078	10 873	7 790	5 706	[<i>N · m</i>]
$M_{2 \min.}$	3 265				[<i>N · m</i>]
$M_{2 \max.}$	4 544				[<i>N · m</i>]

tab. 6 otáčky a krouticí momenty jednotlivých soukolí při záměně vstupního členu s výstupním

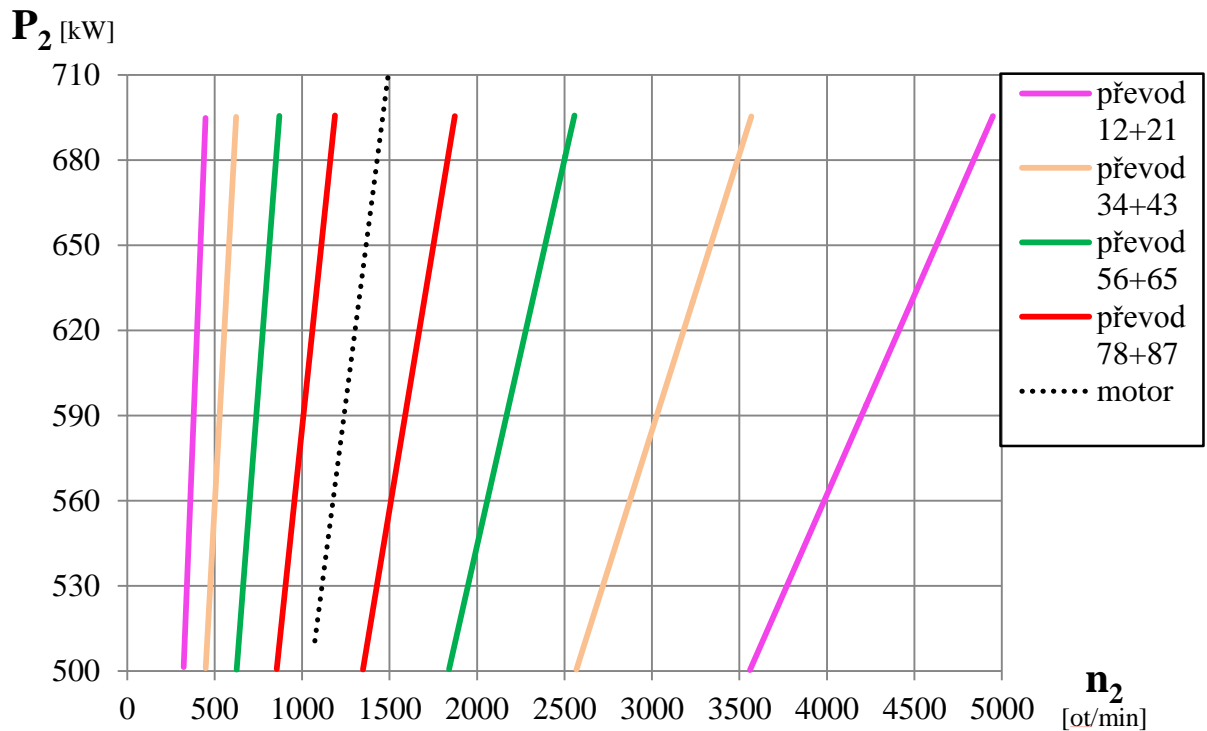
Z tab. 5 a tab. 6 vyplývá, že výsledné převody zkušební převodovky pokryjí výstupní otáčky v rozmezí $324 \div 623$; $626 \div 2 557$; $2 568 \div 4 950$ [*ot./min.*] s využitím asynchronního motoru, který by ve svém pracovním spektru otáček mohl být připojen bez použití pomocné převodovky. Tyto údaje byly prodiskutovány a odsouhlaseny zadavatelem diplomové práce. Pokud by mohl být výstupní výkon proměnlivý, došlo by pouze ke změně minimálních krouticích momentů na hodnoty maximální, což pro další návrhy nemá vliv.

Závislost výstupního momentu na otáčkách při konstantním výkonu $P_2 = 500$ [kW]



graf 2 závislost výstupního momentu na otáčkách při konstantním výkonu

Závislost výstupního výkonu na otáčkách při maximálním kroučicím momentu



graf 3 závislost výstupního výkonu na otáčkách při maximálním kroučicím momentu

3.3 Výpočet mezery mezi šikmými zuby

Při závěrečné úpravě ozubení brusným kotoučem musí být šípovité ozubení oddělené určitou mezerou B nebo musí být jednotlivá kola dělená, což někdy neumožňuje konstrukce a také by to mělo za následek složitou a přesnou montáž. Šípovité ozubení se proto vyrábí většinou z jednoho kusu, kde se šířka věnce šikmé části volí přibližně stejná jako výrobní mezera B . Z obr. 4 lze pomocí matematických vztahů odvodit výslednou mezeru B mezi šikmými zuby, kde je červenou barvou znázorněn brusný kotouč. V tab. 7 jsou vypočítány minimální mezery $B_{min.}$ pro každé ozubené kolo podle zvolených rozměrů potřebných k výpočtu a dále stanovené (zaokrouhlené) výrobní mezery B .

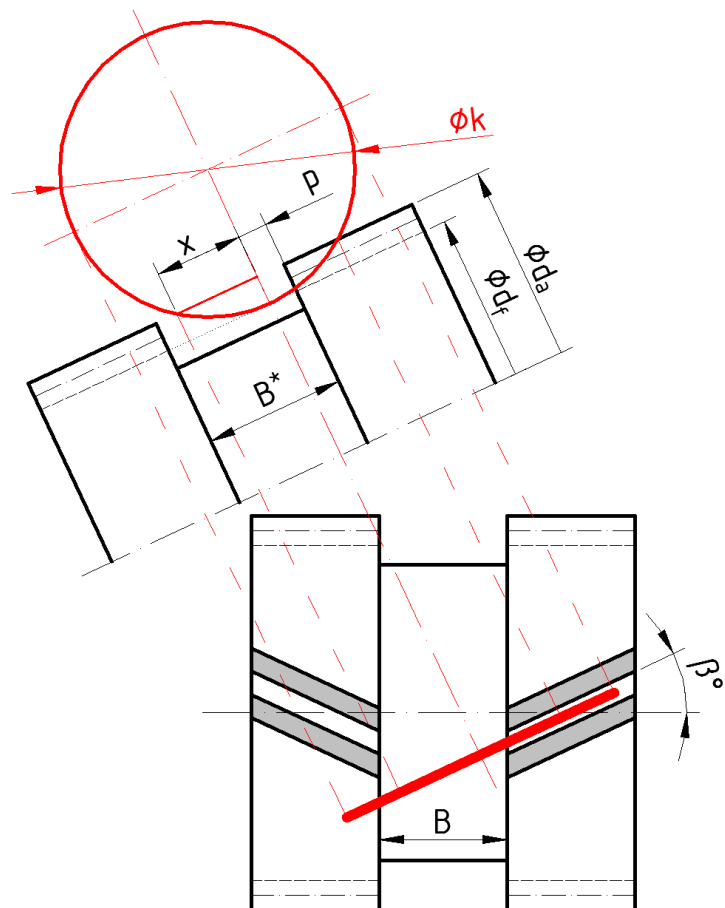
$\phi k = 300$ [mm].....zvolený průměr brusného kotouče
 $p = 10$ [mm].....zvolený přesah pro výjezd brusného kotouče
 $\beta = 25$ [°].....sklon šroubovice šikmého ozubení
 ϕd_ahlavová kružnice obráběného kola (tab. 8)
 ϕd_fpatní kružnice obráběného kola (tab. 8)

$$B_{min.} = B^* \cdot \cos(\beta)$$

$$B^* = x + p$$

$$x = \sqrt{\left(\frac{k}{2}\right)^2 - \left(\frac{k - d_a + d_f}{2}\right)^2}$$

	$B_{min.}$	B
z_1	65,42	70
z_2	65,42	
z_3	65,42	
z_4	65,42	
z_5	65,42	
z_6	65,42	
z_7	64,67	
z_8	64,67	
	[mm]	[mm]



tab. 7 mezery mezi šípovitým ozubením

obr. 4 schéma pro výpočet potřebné mezery B mezi šikmými zuby

3.4 Vstupní data pro návrh ozubení programem KISSOFT

V programu KISSOFT jsem provedl návrh jednotlivých soukolí a zkontroloval jejich bezpečnost. Výhodou tohoto programu je možnost exportovat výslednou zprávu se všemi potřebnými parametry daného soukolí a zároveň export 3D modelu. Výsledné reporty o parametrech ozubených kol jsou uvedeny v „Příloha 1“ této diplomové práce.

Vstupní zadané hodnoty:

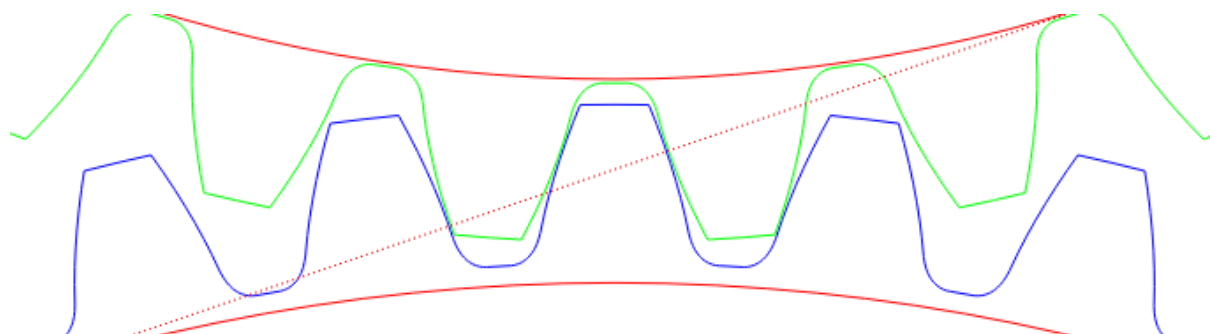
z počet zubů na kole a pastorku viz tab. 4
typ ozubení dvojité šikmé
 m modul ozubení viz tab. 4
 β úhel sklonu zubů viz tab. 4
 $a_w = 315 [mm]$ zvolená osová vzdálenost na základě uvedených hodnot v tab. 4
korekce ozubených kol na měrné skluzy
materiály kol 42CrMo 4 (2) / ISO 6336-5
materiály pastorků 42CrMo 4 (2) / ISO 6336-5
typ mazacího oleje ISO-VG 46
způsob mazání vstřikování oleje do místa záběru
výpočetní norma DIN 3990:1987 metoda B
maximální přenášené zatížení volba krouticího momentu a otáček dle tab. 6
životnost 20 000 hodin
tolerance hlavové kružnice h10
 $K_A = 1,2$ součinitel vnějších dynamických sil dle zadavatele diplomové práce

- profil zubu byl zvolen dle normy „ISO 53.2:1997 profil C“ s normalizovaným úhlem záběru $\alpha = 20 [^\circ]$
- celková šíře soukolí a mezera mezi šípovitým ozubením viz tab. 7, kde celková šíře byla zvolena jako násobek tří potřebné mezery pro výrobu.

Ostatní koeficienty pro výpočet byly po konzultaci s firmou Wikov Gear s.r.o. ponechány na výchozích hodnotách programu.

Výstupní hodnoty:

Výpočet daného soukolí je téměř okamžitý. Základním výsledkem je návrh profilu zubu (obr. 5), základní rozměrové hodnoty a bezpečnosti pro zadaný zátěžný stav, které jsou uvedeny v tab. 8. Výsledné bezpečnosti jsou uvedeny při maximálním možném zátěžném stavu, tj. maximální krouticí moment, který může na daném soukolí nastat, což nastává u převodů i_{21} ; i_{43} ; i_{65} ; i_{87} . Ostatní podrobné hodnoty o jednotlivých převodech jsou uvedeny v „Příloha 1“.



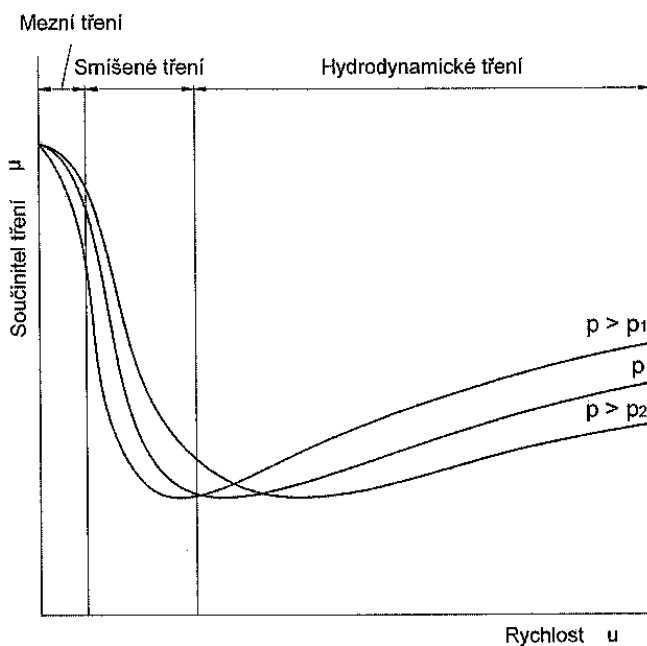
obr. 5 vypočítaný 2D profil zubů

	z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	
bezpečnost v patě zubu	2,982	3,1286	3,6354	3,7748	4,2658	4,3716	5,6004	5,6113	[-]
bezpečnost boku zubu	1,3958		1,6734		1,9223		2,0618		[-]
bezpečnost proti odírání (včetně teploty)	3,4088		3,9256		4,2682		4,1876		[-]
součinitel trvání záběru	2,9849		3,0206		3,0438		3,1907		[-]
jednotková korekce x	-0,1753	0,2654	-0,1041	0,1941	-0,0417	0,1317	-0,5834	-0,3670	[mm]
\varnothing hlavové kružnice d_a	493,17	160,824	454,303	199,691	408,709	245,284	361,733	291,507	[mm]
\varnothing roztečné kružnice d	483,28	145,646	443,558	185,367	397,216	231,709	357,494	284,672	[mm]
\varnothing patní kružnice d_f	466,176	133,83	427,309	172,697	381,715	218,29	335,493	265,267	[mm]
\varnothing základní kružnice d_b	448,466	135,154	411,606	172,015	368,603	215,018	331,742	264,165	[mm]

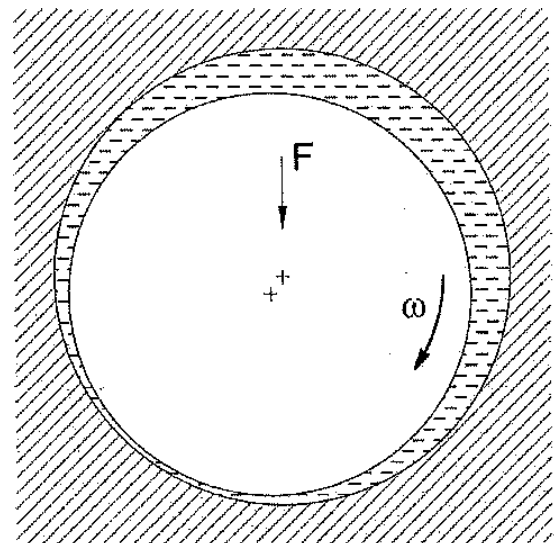
tab. 8 výsledné bezpečnosti jednotlivých ozubených kol + jednotkové korekce a rozměry

4 Výběr hydrodynamických ložisek

Návrh hydrodynamického ložiska je složitým strojírenským oborem. Věda, která se zabývá problematikou tření, se nazývá tribologie. Při vzájemném pohybu dvou kluzných ploch s použitím kapalinového maziva vzniká tření, které může být mezní, smíšené nebo hydrodynamické viz obr. 6. U hydrodynamických ložiskových pánví dochází vlivem zatížení k vytlačování oleje a vlivem rotačního pohybu k vytváření hydrodynamického klínu. Pokud je počet otáček hřídele dostatečně veliký, vzniká v zatížené dolní části prostoru ložiskové vůle účinkem rotace hřídele, viskozity oleje a klínovitého tvaru prostoru ve vrstvě oleje hydrodynamický tlak, který oddělí kluzné plochy hřídele a ložiska a hřídel se vychýlí ve směru rotace, viz obr. 7. Teoreticky by při nekonečně velkém počtu otáček mohl hřídel zaujmout soustřednou polohu v ložisku. Únosnost ložiska závisí na velikosti hydrodynamického tlaku v mazací vrstvě, tj. závisí hlavně na velikosti ložiskové vůle ψ , kluzné rychlosti a viskozitě maziva η . Vzájemnou závislost těchto veličin určuje Sommerfeldovo číslo $So = \frac{p \cdot \psi^2}{\eta \cdot \omega}$ a jeho převrácená hodnota se nazývá ložiskové číslo a . Hydrodynamická ložiska se vyrábí v různých provedeních, která jsou zobrazena v kapitole 4.1. ^[1]

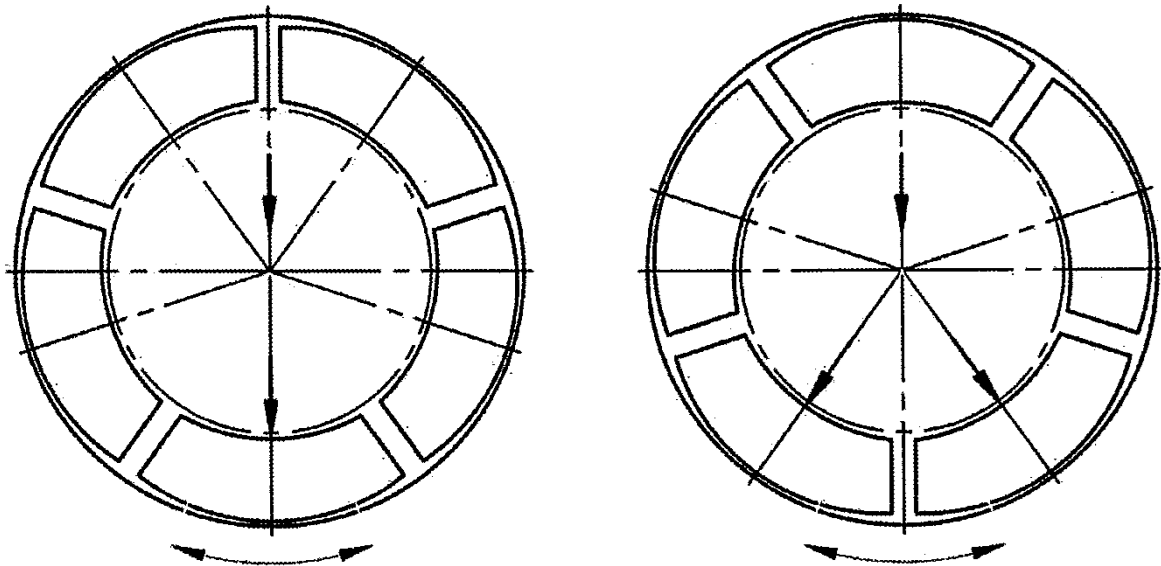


obr. 6 Stribeckovy křivky ^[1]



obr. 7 poloha hřídele při hydrodynamickém mazání ^[1]

Segmentová ložiska jsou výhodná pro vysoké obvodové rychlosti a vyznačují se vysokou tuhostí a útlumem. Tato segmentová ložiska je možné zatěžovat dvěma způsoby, viz obr. 8. Ložisko zatížené mezi segmenty zvýší možné zatížení cca o 1/3 oproti zatěžování na segment. U tohoto typu ložiska se tedy snažíme, aby výsledná reakce působila právě mezi segmenty. Dále jsou všechna hydrodynamická ložiska dělená z technologických a praktických důvodů, viz obr. 9. Vyráběné hodnoty těchto ložisek jsou určeny poměrem šířky k průměru. Nejčastější hodnoty jsou $B/d = 0,4; 0,5; 0,7; 1 [-]$. Ložiska mohou být radiální, axiální nebo radiálně-axiální.


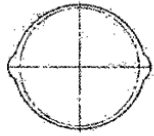


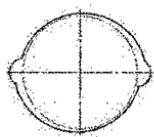

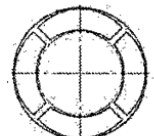
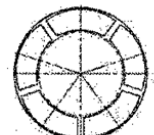


obr. 8 zatížení ložiska „na segment“ a „mezi segmenty“^[1]



obr. 9 ukázka vyráběného hydrodynamického ložiska^[7]

4.1 Typy hydrodynamických ložisek ^[1]

Provedení	Obvodová rychlost [m/s]	Měrný tlak [MPa]	Sommerfeldovo číslo	Tuhost Útlum	Oblast použití
 Válec	0 – 30 (35)	0,2 – 4,5 (5)	0,5 – 10	* *****	převodovky, parní turbíny, elektrické motory, generátory
 Citron	25 – 70 (80)	0,2 – 3,5 (4)	0 – 1,5	** ****	převodovky, parní turbíny, elektrické motory, generátory
 3-Lobe	30 – 90 (100)	0,1 – 3,0 (3,5)	0 – 1,0	*** ***	Obecně pro malé průměry hřídelů s vysokými otáčkami turbodmychadla
 Offset	20 – 90 (100)	0,2 – 3,5 (4,0)	0 – 2,0	*** ****	převodovky, parní turbíny
 Double Offset	20 – 90 (100)	0,2 – 3,5 (4,0)	0 – 2,0	*** ****	převodovky, parní turbíny
 4-Lobe	30 – 90 (100)	0,1 – 2,0 (2,5)	0 – 1,0	*** *	vysokorychlostní pumpy, převodovky, expanzní turbíny, turbíny chlazení, včetně obráběcích strojů
 4-Segmenty	30 – 100	0 – 2,5 (3,0)	0 – 1,0	**** ****	převodovky, parní turbíny, jednohřídelové kompresory
 5-Segmentů	30 – 125 (150)	0 – 3,0 (3,5)	0 – 1,0	***** *****	rychloběžné převodovky, turbokompresory, parní turbíny, plynové turbíny

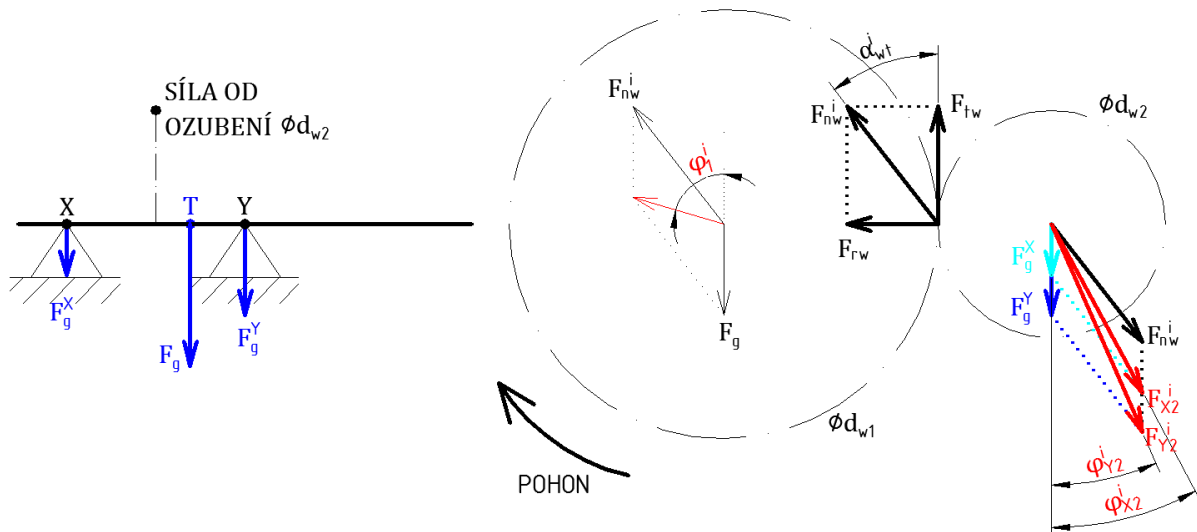
***** Velmi vysoké hodnoty

* Nízké hodnoty

tab. 9 přehled vnitřních profilů hydrodynamických ložisek ^[1]

4.2 Výpočet a výběr vhodných ložisek

Samotný návrh by byl obsahem nové diplomové práce. Firma Wikov Gear s.r.o. nakupuje hydrodynamická ložiska od firmy Waukesha bearings zabývající se touto problematikou. Katalog tohoto výrobce je uveden v „Příloha 2“. K výběru vhodného ložiska je potřeba znát výsledné reakce, které na ně působí. Protože hydrodynamická ložiska jsou poměrně nákladnou záležitostí, budou v této pomocné převodovce použity 4 druhy hydrodynamických ložisek, která budou navržena na maximální zátěžný stav. Tyto 4 ložiska budou tedy využívána pro všechny výměnné převody.



obr. 10 Reakce v uložení vyvozené záběrem zubů a vlastní hmotností soukolí

Z výsledků soukolí v programu KISSOFT dle „Příloha 1“ jsem vyhledal korigovaný čelní úhel záběru α_{wt} a z působících sil spočetl výslednou reakci F_{nw} .

$$F_{nw} = \sqrt{F_{tw}^2 + F_{rw}^2}$$

	i_{12}	i_{21}	i_{34}	i_{43}	i_{56}	i_{65}	i_{78}	i_{87}	
F_{nw}	20 251	67 197	22 065	52 798	24 639	42 238	27 377	34 380	[N]
α_{wt}	22,122		22,122		22,122		18,935		[°]

tab. 10 síly v ozubených převodech

$$\alpha_{wt} = \frac{\text{tg}(\alpha_w)}{\cos(\beta)} = \cos^{-1} \left(\frac{d_{b 1;3;5;7} + d_{b 2;4;6;8}}{2 \cdot a_w} \right) = \text{tg}^{-1} \left(\frac{F_{rw}}{F_{tw}} \right)$$

.....příklad výpočtu čelního úhlu záběru pro korigované soukolí
 kde α_w je v programu KISSOFT značen jako α_{wn} .

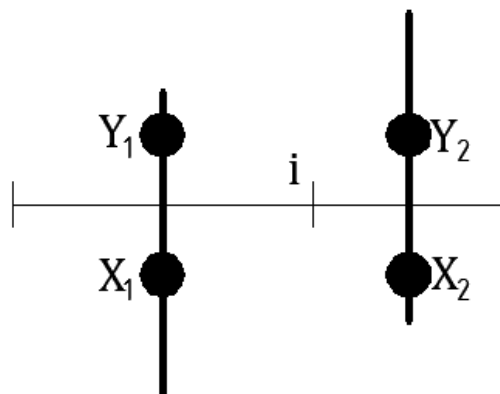
$$F_{X2;1}^i = \sqrt{(F_{nw}^i)^2 + (F_g^X)^2 \pm 2 \cdot F_{nw}^i \cdot F_g^X \cdot \cos(\alpha_{wt}^i)}$$

.....výpočet výsledné reakce v ložisku s uvažováním vlastní tíhy hřídele

Protože zatím nejsou navrženy hřídele (hmotnost a těžiště), zvolím ložiska (velikost) z předběžných sil uvedených v tab. 10, kde jsem výsledné reakce F_{nw} pro každé ložisko vydělil dvěma, protože ozubená kola budou stejně vzdálena od každého ložiska. Z výsledků jsem dle katalogu „Příloha 2“ zvolil základní průměry hřídelů, kde jsem zvolil poměr šířky k průměru roven jedné. Skutečné maximální reakce působící na ložiska při různých převodových poměrech jsou stanoveny v tab. 11 a příslušné značení na obr. 11. Výsledky vyplývají z návrhu hřídelů, viz kapitola 5. Ložiska označená Y_1 ; Y_2 ; X_2 volím radiální a ložisko X_1 jako radiálně-axiální. Radiálně-axiální ložisko je zvoleno na pomaloběžné hřídeli z důvodů menších výkonových ztrát. Z technologického hlediska montáže nelze použít na obě hřídele ložiska s naklápěcími segmenty. Protože je ložisko s naklápěcími segmenty výhodnější pro vysoké obvodové rychlosti, budou tyto ložiska umístěna na rychloběžnou hřídel.

	i_{12}	i_{34}	i_{56}	i_{78}	i_{21}	i_{43}	i_{65}	i_{87}	
F_{X1}	9,044	9,95	11,236	12,579	35,573	27,461	22,213	18,298	[kN]
φ_{X1}	24,94	24,68	24,39	20,68	20,79	21,2	20,98	17,74	[°]
F_{Y1}	9,716	10,623	11,91	13,27	34,886	26,776	21,528	17,598	[kN]
φ_{Y1}	23,11	23,02	22,93	19,56	21,22	21,76	21,68	18,47	[°]
	působí nad dělicí rovinou				působí pod dělicí rovinou				
F_{X2}	10,282	11,259	12,649	14,16	33,441	26,171	20,787	16,715	[kN]
φ_{X2}	21,76	21,65	21,51	18,27	22,23	22,33	22,5	19,49	[°]
F_{Y2}	10,568	11,544	12,935	14,451	33,157	25,888	20,504	16,426	[kN]
φ_{Y2}	21,15	21,09	21,01	17,89	22,43	22,58	22,82	19,85	[°]
	působí pod dělicí rovinou				působí nad dělicí rovinou				

tab. 11 reakce působící na ložiska při maximálním zatížení pro jednotlivé převody



obr. 11 značení ložisek (v dělicí rovině)

Výběr ložisek:

Průměr hřídele pod ložiskem X_1 a Y_1 je 140 [mm]. Musí být menší než $d_{f7} = 335,493$ [mm].

Průměr hřídele pod ložiskem X_2 a Y_2 je 110 [mm]. Musí být menší než $d_{f2} = 133,83$ [mm].

Ložiska X_1 a Y_1 volím dle tab. 9 v provedení „válec“ s poměrem $B/d = 0,75$ [-]. (Obvyklé hodnoty šířky k průměru v provedení válcového profilu $B/d = 0,5; 0,75; 1$.)

$$v_{max.} = \omega_{max.} \cdot r = \frac{\pi \cdot d \cdot n_{max.}}{60} = \frac{\pi \cdot 0,14 \cdot 1492}{60} = 10,9 \left[\frac{m}{s} \right]$$

..... maximální obvodová rychlost pomaloběžné hřídele (kontrola obvodové rychlosti v tab. 9)

$$B = 0,75 \cdot 140 = 105 \text{ [mm]} \text{ šířka ložiskové pánve}$$

$$S = B \cdot d = 105 \cdot 140 = 14\,700 \text{ [mm}^2\text{]} \text{ zátěžná plocha ložiskové pánve}$$

$$p_{max.} = \frac{F_{max.}}{S} = \frac{35\,573}{14\,700} = 2,42 \text{ [MPa]} \text{ měrný tlak (kontrola měrného tlaku v tab. 9)}$$

Ložiska X_2 a Y_2 volím dle maximálního zatížení, viz tab. 11, jako segmentová ložiska vyráběná firmou Waukesha Bearings s označením TF 110 – 110. Maximální zatížení tohoto ložiska na segment je 25,4 [kN] a mezi segmenty 33,9 [kN]. Ložisko je čtyř-segmentové. Sudý počet segmentů je výhodný, protože při záměně hnacího hřídele za hnaný se reakce na ložisko otočí o 180 [°] a oba zátěžné stavy působí tak mezi segmenty. Výrobce ložiska poskytuje také graf závislosti ztrátového výkonu a průtočného množství oleje na otáčkách hřídele, viz „Příloha 2“.

$$v_{max.} = \omega_{max.} \cdot r = \frac{\pi \cdot d \cdot n_{max.}}{60} = \frac{\pi \cdot 0,11 \cdot 4\,950}{60} = 28,5 \left[\frac{m}{s} \right]$$

..... maximální obvodová rychlost rychloběžné hřídele (kontrola obvodové rychlosti v tab. 9)

$$Q_{max.} = 0,2 \left[\frac{l}{s} \right] \text{ maximální potřebný průtok oleje pro jedno ložisko}$$

$$P_{Z\,max.} = 5 \text{ [kW]} \text{ maximální ztrátový výkon jednoho ložiska}$$

Z důvodů ochrany ložisek před zadřením se u každého ložiska musí kontrolovat teplota oleje v místě působení maximální zátěžné síly. Tyto úhly se vlivem výměnných převodů mění a jsou uvedeny v tab. 11. Jako měřicí úhly bych z výsledků stanovil převody i_{78} a i_{21} . Z toho vyplývá, že by bylo potřeba každé ložisko měřit na dvou odlišných místech pootočených o cca 180 [°], tj. v horní a spodní části převodové skříně.

5 Návrh hřídelů

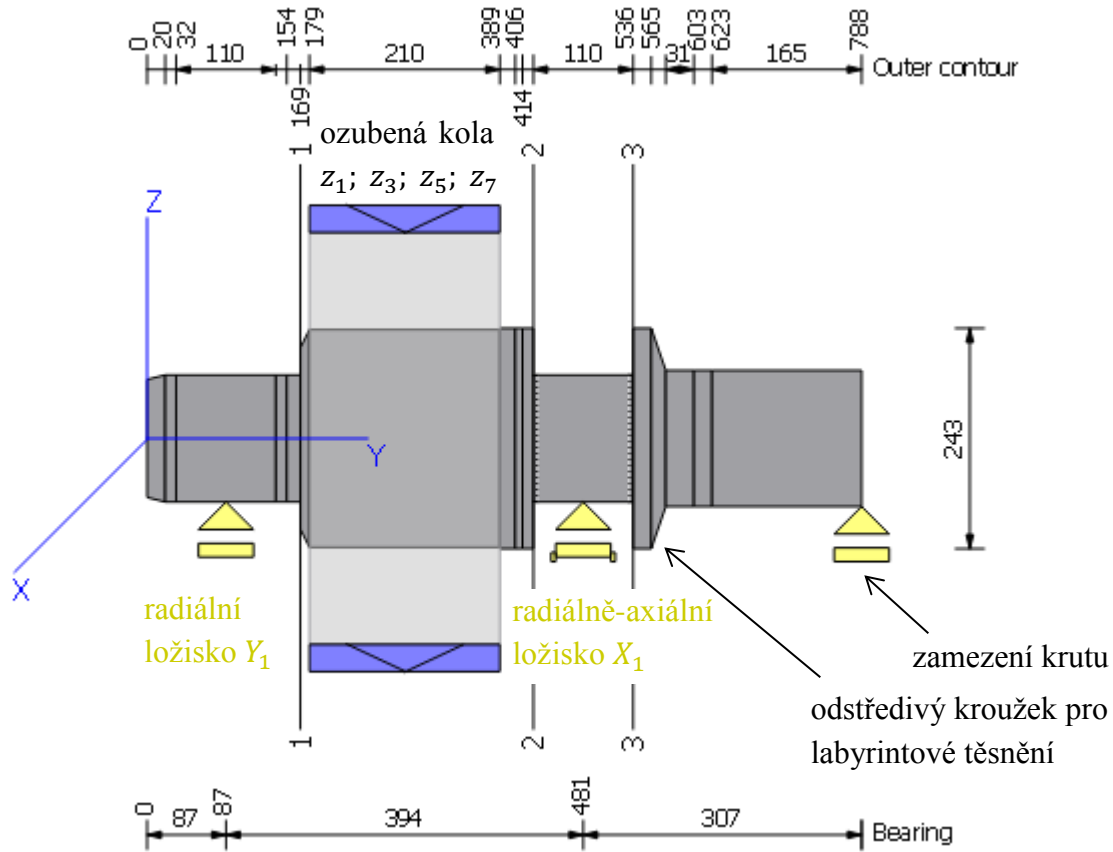
Návrh a výpočet hřídelů byl proveden v programu KISSOFT, viz Příloha 3. Pro zkušební převodovku musí být vyrobeno celkem 8 kusů hřídelí. Z hlediska usnadnění výroby jsem zvolil pro každý převod hřídele stejných rozměrů, viz obr. 12 a obr. 13. Pro výpočet bylo zadáno zatížení převzaté z výsledků jednotlivých ozubení. Důležitým parametrem bylo určení směru rotace otáčení a pozice spolu zabírajícího kola, který určuje výsledný směr a velikost reakcí v ložiskách, viz Příloha 3. Při výpočtu bylo uvažováno s vlastní hmotností hřídele a zadaný materiál jsem zvolil „C45 (1)“. O tom, která ozubená kola budou na hřídel nalisována nebo která budou vyrobena spolu s hřídelí, je uvedeno v kapitole 6. V kritických (vrubových) místech byla provedena kontrola na cyklické namáhání, kde všechny hřídele mají neomezenou životnost. Základní hodnoty výsledků jsou shrnuty v tab. 12 a tab. 13. Maximální průhyby jsou v koncových místech hřídelů, tj. v připojení pro spojku.

	i_{12}	i_{21}	i_{34}	i_{43}	i_{56}	i_{65}	i_{78}	i_{87}	
maximální napětí	16,17	54,06	16,33	39,29	16,56	28,59	16,81	21,27	[MPa]
maximální průhyb	3,58	5,98	3,86	7,45	4,25	5,86	4,67	4,66	[μ m]
hmotnost	165								[kg]

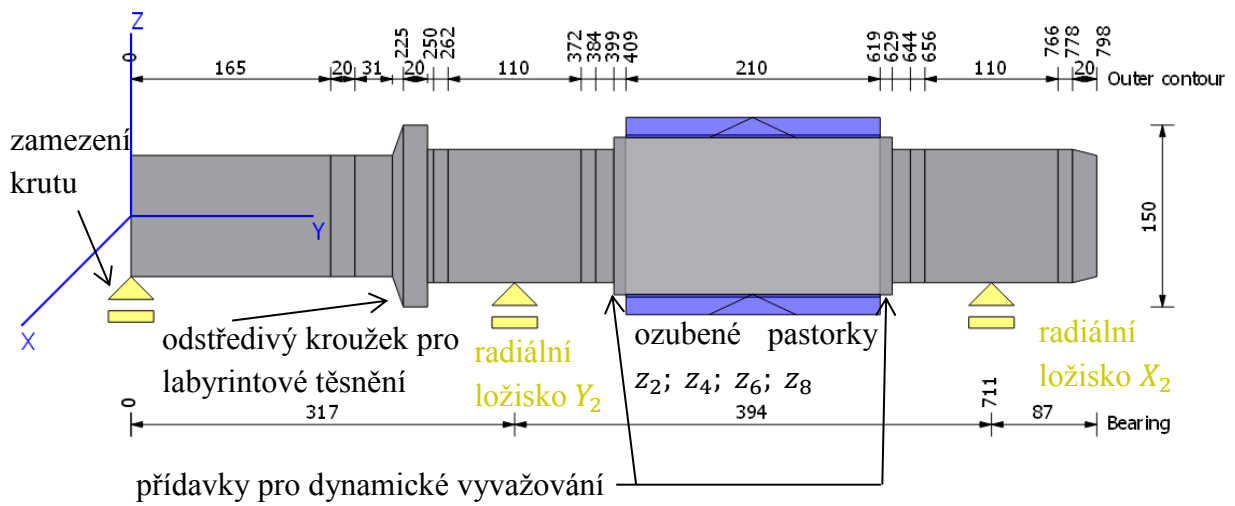
tab. 12 výsledné hodnoty pomaloběžných hřídelů značených (1; 3; 5; 7)

	i_{12}	i_{21}	i_{34}	i_{43}	i_{56}	i_{65}	i_{78}	i_{87}	
maximální napětí	13,16	43,69	16,79	40,1	23,4	40,1	31,93	40,1	[MPa]
maximální průhyb	20,54	72,09	13,37	34,75	11,59	21,83	11,68	16,1	[μ m]
hmotnost	66								[kg]

tab. 13 výsledné hodnoty rychloběžných hřídelů značených (2; 4; 6; 8)



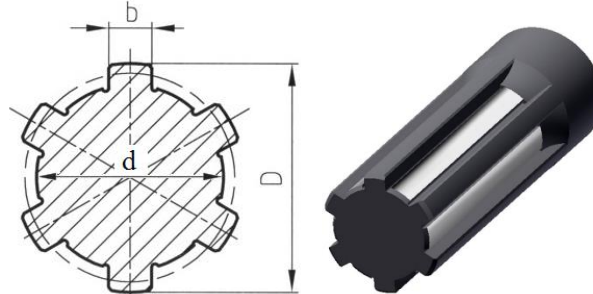
obr. 12 pomaloběžná hřídel



obr. 13 rychloběžná hřídel

5.1 Výpočet spoje pro spojku

Připojení hřídele ke kotoučové spojce volím pomocí drážkového spoje, viz obr. 14, kde dovolený tlak je $p_d = 60 \text{ [MPa]}$. Délku rovnobokého drážkování volím $L = 100 \text{ [mm]}$. Výpočet je pouze kontrolou pro navržený typ rovnobokého drážkování s ohledem na rozměry hřídelí.



obr. 14 rovnoboké drážkování

Rovnoboké drážkování na rychloběžných hřídelích:

$M_{k \max.} = 4\,544 \text{ [N} \cdot \text{m]}$ maximální krouticí moment přenášený rovnobokým drážkováním

10 x 102 x 108..... značení rovnobokého drážkování

$$F_o = \frac{4 \cdot M_{k \max.}}{d + D} = \frac{4 \cdot 4\,544}{0,102 + 0,108} = 86\,552 \text{ [N]} \dots\dots \text{obvodová síla}$$

$$S_{\text{zatěžovaný}} = 0,75 \cdot \frac{D - d}{2} \cdot L \cdot z = 0,75 \cdot \frac{108 - 102}{2} \cdot 100 \cdot 10 = 2\,250 \text{ [mm}^2\text{]} \dots\dots$$

..... plocha zatěžovaných boků zubů

$$p_{\text{měrný}} = \frac{F_o}{S_{\text{zatěžovaný}}} = \frac{86\,552}{2\,250} = 38,5 \text{ [MPa]} \leq p_d \quad \checkmark \text{ vyhovuje}$$

Rovnoboké drážkování na pomaloběžných hřídelích:

$$M_{k \max.} = 15\,078 \text{ [N} \cdot \text{m]}$$

10 x 130 x 140

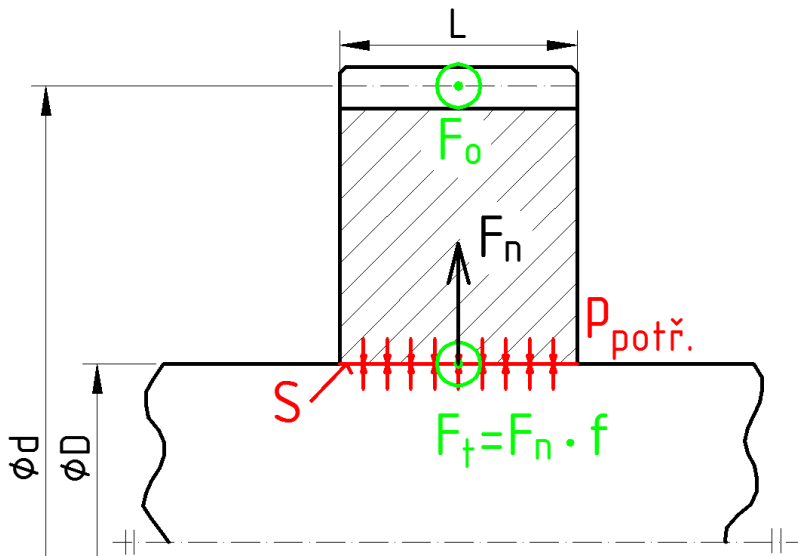
$$F_o = \frac{4 \cdot M_{k \max.}}{d + D} = \frac{4 \cdot 15\,078}{0,13 + 0,14} = 223\,378 \text{ [N]}$$

$$S_{\text{zatěžovaný}} = 0,75 \cdot \frac{D - d}{2} \cdot L \cdot z = 0,75 \cdot \frac{140 - 130}{2} \cdot 100 \cdot 10 = 3\,750 \text{ [mm}^2\text{]}$$

$$p_{\text{měrný}} = \frac{F_o}{S_{\text{zatěžovaný}}} = \frac{223\,378}{3\,750} = 59,6 \text{ [MPa]} \leq p_d \quad \checkmark \text{ vyhovuje}$$

6 Nalisování

Ozubené kolo může být na hřídel nalisováno za tepla nebo za studena. Vlivem uložení s přesahem vzniká ve spoji tlak, který umožní přenášet točivý moment z ozubeného kola na hřídel. U rychloběžných převodovek může také dojít k uvolnění spoje vlivem odstředivé síly, která působí na obě hmoty. Proto uvažují i s touto silou. Z hlediska výroby je lépe obrobitelná hřídel než díra. Proto má díra většinou větší toleranční pole oproti hřídeli. Toleranční pole díry je zvoleno na H7 a příslušná tolerance hřídele musí být doložena.



obr. 15 silové účinky v nalisovaném spoji

$S = \pi \cdot D \cdot L$ plocha přenášející točivý moment

$S_f = 2,5 [-]$ bezpečnost lisovaného spoje

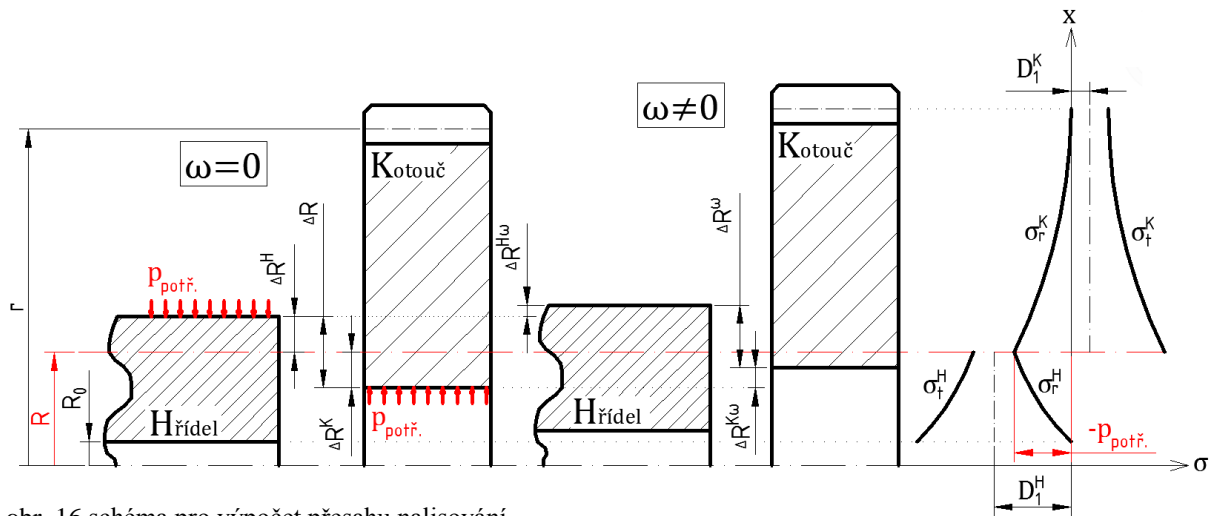
$f = 0,2 [-]$ koeficient tření mezi hřídelí a ozubeným kolem po nalisování za tepla

$M_k = F_o \cdot \frac{d}{2} = F_t \cdot \frac{D}{2}$ krouticí moment pro vyjádření tečné síly pro lisovaný spoj

$p_{potř.} = \frac{F_n}{S} \cdot S_f = \frac{F_t}{\pi \cdot D \cdot L} \cdot S_f = \frac{2 \cdot M_k \cdot S_f}{\pi \cdot D^2 \cdot L \cdot f}$

..... potřebný tlak pro přenesení maximální kroutícího momentu

6.1 Výpočet přesahu, který vyvolá potřebný tlak



obr. 16 schéma pro výpočet přesahu nalisování

$$\Delta R = |\Delta R^H| + \Delta R^K$$

$$\Delta R^\omega = \Delta R + \Delta R^{H\omega} - \Delta R^{K\omega}$$

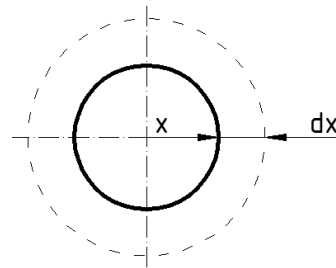
Přetvoření silnostěnné nádoby získáme pomocí poměrné deformace a Hookova zákona, kde $\nu [-]$ je Poissonovo číslo.

$$\varepsilon_t = \frac{2 \cdot \pi \cdot (x + \Delta x) - 2 \cdot \pi \cdot x}{2 \cdot \pi \cdot x} = \frac{\Delta x}{x}$$

$$\varepsilon_t = \frac{1}{E} \cdot (\sigma_t - \nu \cdot \sigma_r)$$

⇓

$$\Delta x = \frac{x}{E} \cdot (\sigma_{t(x)} - \nu \cdot \sigma_{r(x)})$$



obr. 17 přetvoření silnostěnné nádoby

Obecné průběhy tečného a radiálního napětí, když $\omega = 0 [rad/s]$, jsou zobrazeny na obr. 16. Výsledné vztahy jsou určeny na základě teorie silnostěnných nádob. Koeficienty D_1 a D_2 jsou určeny z okrajových podmínek.

$$\sigma_{r(x)} = D_1 - \frac{D_2}{x^2}$$

$$\sigma_{t(x)} = D_1 + \frac{D_2}{x^2}$$

⇓

$$\sigma_{r(x)} + \sigma_{t(x)} = 2 \cdot D_1$$

$$\sigma_{r(R_0)}^H = 0 \quad \sigma_{r(R)}^K = -p_{potř.}$$

$$\sigma_{r(R)}^H = -p_{potř.} \quad \sigma_{r(r)}^K = 0$$

⇓

$$D_1^H = \frac{-p_{potř.} \cdot R^2}{R^2 - R_0^2}$$

$$D_1^K = \frac{p_{potř.} \cdot R^2}{r^2 - R^2}$$

6.1.1 Změna rozměru hřídele

$$\Delta R^H = \frac{R}{E^H} \cdot (\sigma_{t(R)}^H - \nu^H \cdot \sigma_{r(R)}^H)$$

$$\sigma_{t(R)}^H = 2 \cdot D_1^H + p_{potř.}$$

po dosazení $\sigma_{t(R)}^H$ a $\sigma_{r(R)}^H$:

$$\Delta R^H = -\frac{R \cdot p_{potř.}}{E^H} \cdot \frac{R^2 \cdot (1 - \nu^H) + R_0^2 \cdot (1 + \nu^H)}{R^2 - R_0^2}$$

6.1.2 Změna rozměru kotouče

$$\Delta R^K = \frac{R}{E^K} \cdot (\sigma_{t(R)}^K - \nu^K \cdot \sigma_{r(R)}^K)$$

$$\sigma_{t(R)}^K = 2 \cdot D_1^K + p_{potř.}$$

po dosazení $\sigma_{t(R)}^K$ a $\sigma_{r(R)}^K$:

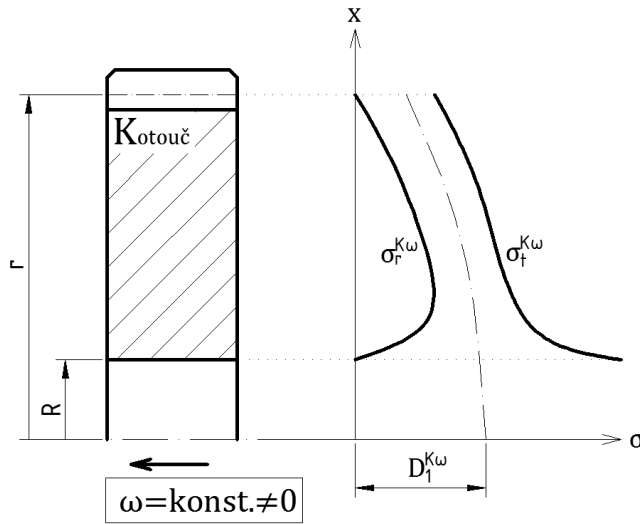
$$\Delta R^K = \frac{R \cdot p_{potř.}}{E^K} \cdot \frac{R^2 \cdot (1 - \nu^K) + r^2 \cdot (1 + \nu^K)}{r^2 - R^2}$$

Potřebný přesah nalisovaného spoje, který způsobí tlak $p_{potř.}$:

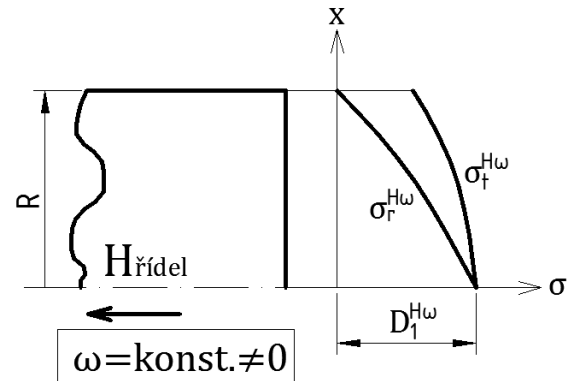
$$\Delta R = R \cdot p_{potř.} \cdot \left[\frac{R^2 \cdot (1 - \nu^H) + R_0^2 \cdot (1 + \nu^H)}{E^H \cdot (R^2 - R_0^2)} + \frac{R^2 \cdot (1 - \nu^K) + r^2 \cdot (1 + \nu^K)}{E^K \cdot (r^2 - R^2)} \right]$$

6.2 Změna rozměrů při rotaci:

Obecné průběhy tečného a radiálního napětí, když $\omega \neq 0$ [rad/s], jsou zobrazeny na obr. 18 a obr. 19. Výsledné vztahy jsou určeny na základě teorie rotujícího kotouče stálé tloušťky. Koeficienty D_1 a D_2 jsou určeny z okrajových podmínek.



obr. 18 průběh napětí v kotouči způsobený vlastní rotací



obr. 19 průběh napětí v hřídeli způsobený vlastní rotací

$$\sigma_{r(x)}^{\omega} = D_1^{\omega} - D_{\omega} \cdot (3 + \nu) \cdot x^2 - \frac{D_2^{\omega}}{x^2}$$

$$\sigma_{t(x)}^{\omega} = D_1^{\omega} - D_{\omega} \cdot (1 + 3 \cdot \nu) \cdot x^2 + \frac{D_2^{\omega}}{x^2}$$

$$D_{\omega} = \frac{\rho \cdot \omega^2}{8}$$

$$\sigma_{r(R)}^{K\omega} = 0 \quad \sigma_{r(0)}^{H\omega} = \sigma_{t(0)}^{H\omega}$$

$$\sigma_{r(r)}^{K\omega} = 0 \quad \sigma_{r(R)}^{H\omega} = 0$$

⇓

$$D_1^{K\omega} = D_{\omega}^K \cdot (3 + \nu^K) \cdot (R^2 + r^2)$$

$$D_2^{K\omega} = D_{\omega}^K \cdot (3 + \nu^K) \cdot R^2 \cdot r^2$$

$$D_1^{H\omega} = D_{\omega}^H \cdot (3 + \nu^H) \cdot R^2$$

$$D_2^{H\omega} = 0$$

6.2.1 Změna rozměru kotouče

$$\Delta R^{K\omega} = \frac{R}{E^K} \cdot (\sigma_{t(R)}^{K\omega} - \nu^K \cdot \sigma_{r(R)}^{K\omega})$$

$$\sigma_{t(R)}^{K\omega} = 2 \cdot D_{\omega}^K \cdot [R^2 \cdot (1 - \nu^K) + r^2 \cdot (3 + \nu^K)]$$

po dosazení $\sigma_{t(R)}^{K\omega}$ a $\sigma_{r(R)}^{K\omega}$:

$$\Delta R^{K\omega} = \frac{2 \cdot D_{\omega}^K \cdot [R^2 \cdot (1 - \nu^K) + r^2 \cdot (3 + \nu^K)] \cdot R}{E^K}$$

6.2.2 Změna rozměru plného hřídele

$$\Delta R^{H\omega} = \frac{R}{E^H} \cdot (\sigma_{t(R)}^{H\omega} - \nu^H \cdot \sigma_{r(R)}^{H\omega})$$

$$\sigma_{t(R)}^{H\omega} = 2 \cdot D_{\omega}^H \cdot R^2 \cdot (1 - \nu^H)$$

po dosazení $\sigma_{t(R)}^{H\omega}$ a $\sigma_{r(R)}^{H\omega}$:

$$\Delta R^{H\omega} = \frac{2 \cdot D_{\omega}^H \cdot R^3 \cdot (1 - \nu^H)}{E^H}$$

↓

$$\Delta R^{H\omega} < \Delta R^{K\omega}$$

↓

$\Delta R_{\omega} = \Delta R^{K\omega} - \Delta R^{H\omega}$ odlehnutí kotouče od hřídele vlivem rotace

Vlivem rotace vzniká odlehnutí kotouče od hřídele o ΔR_{ω} , proto je potřeba toto odlehnutí přičíst k potřebnému přesahu ΔR a na tento celkový přesah ΔR_{celk} navrhnout vhodné uložení.

6.2.3 Přesah pro lisování rotujících kotoučů

Následující graf 4 znázorňuje vliv rotace na lisovaný spoj, který by byl uvažován a počítán bez ní. Pro sestrojení grafu jsem použil tyto parametry a konstanty:

$P = 510 [kW]$	přenášený výkon spoje
$\nu = \nu^H = \nu^K = 0,3 [-]$	Poissonovo číslo
$E = E^H = E^K = 2,1 \cdot 10^5 [MPa]$	Youngův modul pružnosti v tahu
$\rho = \rho^H = \rho^K = 7\,860 \left[\frac{kg}{m^3}\right]$	hustota materiálu
$S_f = 2,5 [-]$	bezpečnost spoje na přenesení točivého momentu
$f = 0,2 [-]$	koeficient tření po nalisování za tepla
$L = 200 [mm]$	délka lisovaného spoje
$d = 500 [mm]$	průměr kotouče
$D = 250 [mm]$	průměr hřídele
$R_0 = 0 [mm]$	rozměry hřídele a kotouče

$$\Delta D = 2 \cdot \Delta R$$

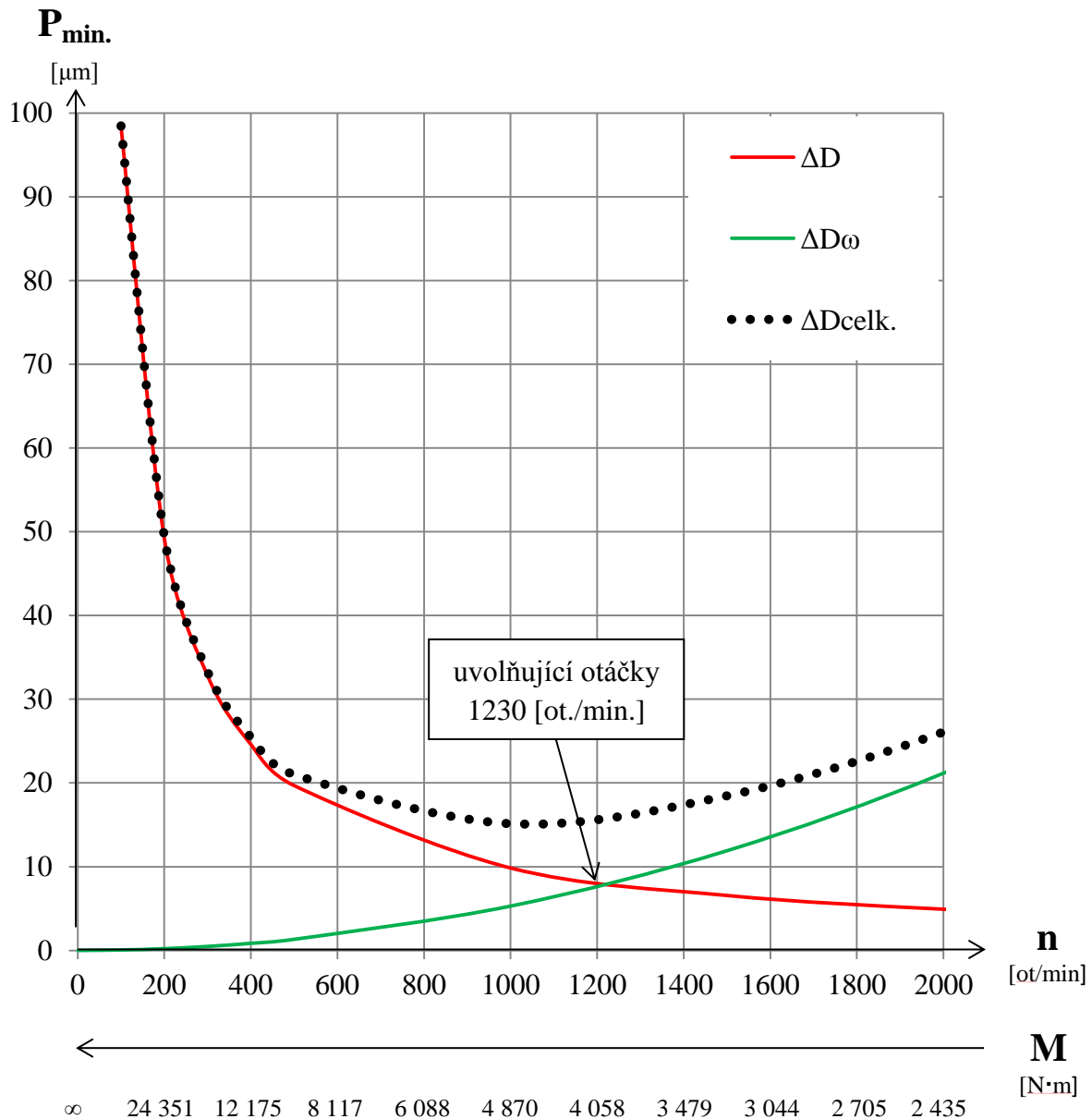
$$\Delta D_{\omega} = 2 \cdot \Delta R_{\omega}$$

$$\Delta D_{celk.} = \Delta D + \Delta D_{\omega} = 2 \cdot (\Delta R + \Delta R_{\omega})$$

Uvolňující otáčky lisovaného spoje pro stejný materiál a plnou hřídel:

$$n = \frac{1}{\pi} \cdot \sqrt{\frac{2 \cdot p_{potř.}}{(3 + \nu) \cdot \rho \cdot (r^2 - R^2)}}$$

Přesah pro nalisování rotujících kotoučů při P=510 [kW]



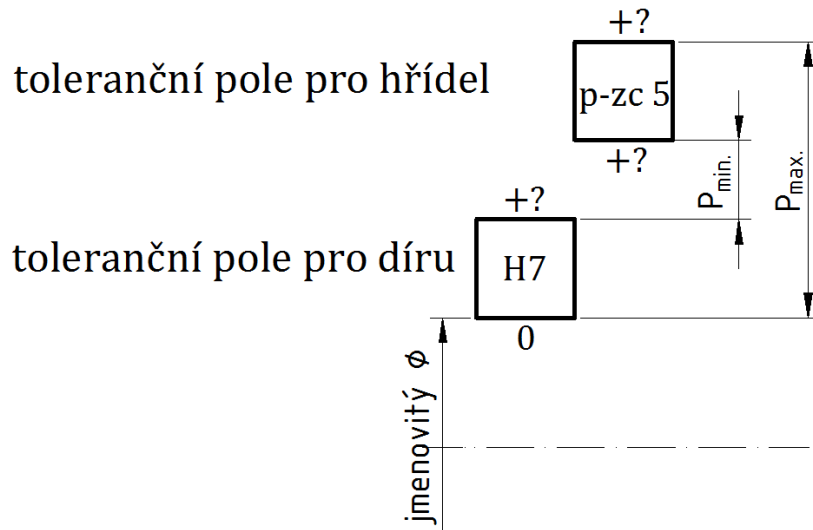
graf 4 minimální přesah pro nalisování rotujících kotoučů při konstantním výkonu

Z grafu je patrné, že pokud spoj dimenzujeme pouze na točivý moment (červená čára) a neuvažujeme otáčení hřídele (zelená čára), stává se spoj od určitého místa poddimenzován od hodnoty cca. $1/3$ uvolňujících otáček spoje při bezpečnosti $S_f \approx 1,1$.

Od tohoto místa směrem k vyšším otáčkám je nutné uvažovat vliv rotace nebo logaritmičsky navyšovat bezpečnost spoje na přenesení potřebného točivého momentu. U rychloběžných převodovek je tedy potřeba uvažovat s tímto vloženým odlehnutím. Protože se navržená převodovka pro testování průmyslových převodovek využívá v pomaloběžném i rychloběžném režimu, musí být lisovaný spoj navržen na takový zátěžný stav, který způsobí největší odlehnutí $\Delta D_{celk.}$

6.3 Výběr vhodného uložení

Na základě celkového potřebného přesahu $\Delta D_{celk.}$ a tolerovanou díru H7 musíme najít minimální přesah uložení $P_{min.}$, který může nastat a který musí být větší než $\Delta D_{celk.}$.



obr. 20 uložení s přesahem

Jednotlivé uložení každého soukolí je shrnuto v tab. 14.

6.4 Ohřátí potřebné pro montáž lisovaného spoje

Rozdíl teplot pro montáž je určen z poměrné deformace a teplotní roztažnosti látky, kde α [$1/K$] je součinitel teplotní roztažnosti.

$$\varepsilon_t = \frac{\Delta P_{max.} + v}{D} = \alpha \cdot \Delta t$$

⇓

$$\Delta t = \frac{\Delta P_{max.} + v}{D \cdot \alpha}$$

$$v = (0,006 \div 0,012) \cdot \sqrt{D} \dots\dots\dots \text{přibližné vůle pro montáž}$$

$$\alpha = 11 \cdot 10^{-6} \left[\frac{1}{K} \right] \dots\dots\dots \text{součinitel délkové roztažnosti pro chromovou ocel}$$

6.5 Výsledné uložení jednotlivých ozubených kol

Výpočet uložení jednotlivých kol byl proveden pomocí programu Excel, kde byl vybrán nejtěžší zátěžný stav, který způsobí největší potřebný přesah nalisování. Výsledná uložení jednotlivých kol na hřídele jsou zobrazena v tab. 14. Ozubené pastorky z_2 a z_4 nelze kvůli malým rozměrům lisovat a je nutné je vyrobit spolu s hřídelí.

$\nu = \nu^H = \nu^K = 0,3 [-]$	Poissonovo číslo
$E = E^H = E^K = 2,1 \cdot 10^5 [MPa]$	Youngův modul pružnosti v tahu
$\rho = \rho^H = \rho^K = 7\,850 \left[\frac{kg}{m^3}\right]$	hustota materiálu
$S = 2 [-]$	bezpečnost spoje na zatížení vůči $\Delta D_{celk.}$
$f = 0,2 [-]$	koeficient tření po nalisování za tepla
$L = 210 [mm]$	délka lisovaného spoje
$R_0 = 0 [mm]$	rozměr hřídele

	z_1	z_3	z_5	z_6	z_7	z_8	
nevyšší zátěžný stav							
M_k	3 265	10 873	7 790	4 544	5 698	4 544	$[N \cdot m]$
n	1 492	449	626	1 073	855	1 073	$[ot./min.]$
D	240	200	150	120	150	120	$[mm]$
ΔD	2,606	9,85	8,744	7,47	6,665	6,648	$[\mu m]$
D_ω	10,55	0,67	0,784	0,627	1,185	0,947	$[\mu m]$
$\Delta D_{celk.} \cdot S$	26,312	20,5	19,06	16,194	15,7	15,19	$[\mu m]$
uložení	H7/r5	H7/r5	H7/r5	H7/r5	H7/r5	H7/r5	$[-]$
$P_{min.}/P_{max.}$	38/104	31/97	25/83	19/69	25/83	19/69	$[\mu m]$
Δt	98	108	125	135	125	135	$[^\circ C]$

tab. 14 stavy nalisování pro jednotlivá ozubená kola

7 Návrh převodové skříně

Při návrhu převodové skříně jsem vycházel z požadovaných vlastností zadání a výpočtů. Prvním krokem bylo vygenerování 3D modelů jednotlivých ozubených kol a pastorků. Následně byla vymodelována jednotlivá hydrodynamická ložiska o rozměrech uvedených v „Příloha 2“. Jednotlivé hřídele byly vymodelovány podle výpočtů v kapitole 5.

Uložení jednotlivých převodů s hydrodynamickými ložisky je zajištěno pomocí převodové skříně, která je vzhledem zadání modelována jako svařenec. Převodová skříň musí zajistit všechny potřebné vlastnosti pro funkci převodovky, například mazání všech funkčních komponent, odvod maziva, tuhost, dynamické namáhání, manipulaci, ochranu před nečistotami atd. Pro tuto pomocnou převodovku jsem zvolil dělenou skříň, která se skládá z víka a spodní části. Dělicí rovina se nachází v úrovni os hřídelí. Základem svařované převodové skříně jsou výpalky plechů o různých tloušťkách a bramy (odlévané desky velké tloušťky), ze kterých je převodová skříň tvořena. Materiál převodové skříně musí být zaručeně svařitelný, proto bych k výrobě použil běžnou konstrukční ocel 11 373, která má mez kluzu $R_e = 220 [MPa]$. Víko a spodní část převodové skříně jsou zobrazeny na obr. 21 a obr. 22. Pro výrobu obou částí jsem využil plechů tloušťky 3; 10; 15 a 30 [mm]. Hmotnost spodního dílu je cca 361 [Kg] a víka cca 323 [Kg]. Spodní část převodové skříně se skládá z celkem 22 plechů a víko je složeno ze 14 plechů. Převodová skříň je 935 [mm] dlouhá, 670 [mm] široká a 585 [mm] vysoká. Dělicí rovina je umístěna ve výšce 310 [mm]. Na obrázcích jsou vyznačeny potřebné svary žlutou barvou.

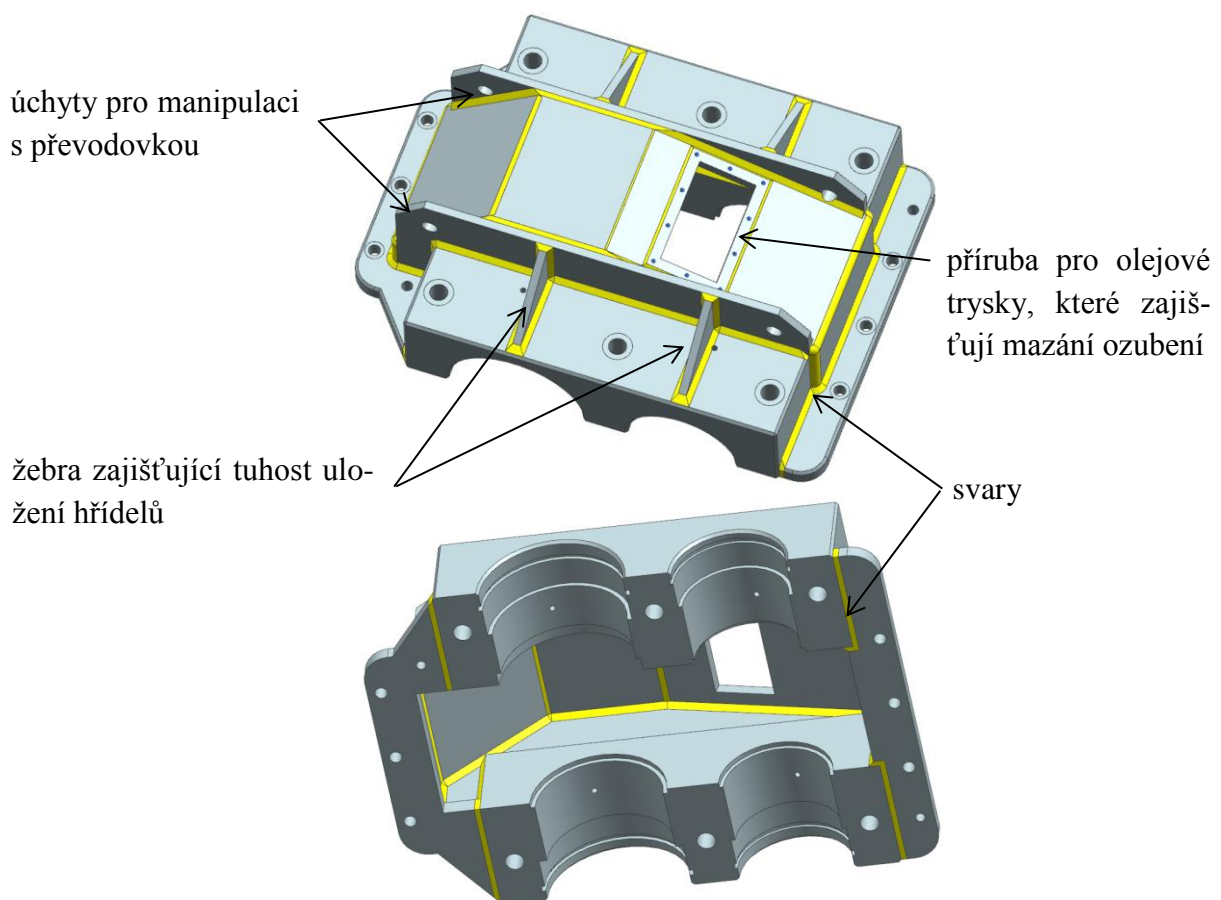
Spojení obou částí převodové skříně je zajištěno dvěma druhy šroubů. Prvním typem je 6 hlavních šroubů vyráběných na míru, které přenášejí zatížení vzniklé od záběru zubů a zamezují tak otevření víka převodové skříně a případné havárii. Druhým typem jsou normalizované šrouby, které zajišťují těsnost převodové skříně po celém obvodu dělicí roviny. Všechny šrouby jsou zajištěny proti povolání druhou maticí. Přesnou polohu spodní části s víkem převodové skříně vymezují dva kuželové kolíky.

Převodová skříň musí být ustavena v požadované poloze na stabilním podloží. Proto jsou ve spodní části přivařeny dvě takzvané patky, za které lze převodovou skříň ustavit např. šrouby nebo upínkami. Pro zvýšení tuhosti a odolnosti proti dynamickému namáhání se převodové skříně opatřují žebrováním, které se zpravidla nachází v blízkosti uložení jednotlivých hřídelí. Další důležitou vlastností převodové skříně je přívod a odvod mazacího oleje do všech potřebných míst. Prvním je způsob mazání ozubeného převodu. Pro kvalitní mazání a minimalizaci ztrát vznikajících např. broděním zubů v olejové lázni je tato pomocná převodovka mazána přímým vstřikem oleje do zubového záběru. Víko převodové skříně je proto opatřeno přírubou, do které se uchytlí olejové trysky. Pro šípovitě ozubení je doporučen směr otáčení ve směru jednotlivých šípů, aby byl olej vlivem odstředivé síly vytlačován a nedocházelo k jeho případnému přehřívání. Druhým potřebným místem pro mazání jsou hydrodynamická ložiska. Rozvod oleje v ložisku je zajištěn drážkou po obvodu, která je dána výrobcem ložiska. Přístup oleje do těchto drážek je umožněn vývrtem a drážkou v dělicí rovině ve spodní části převodové skříně, viz obr. 22. Protože vznikem rotace hřídele dochází v hydrodynamickém ložisku ke vzniku tlaku, je potřeba na vnější straně ložiska zajistit dostatečně velký odvod oleje, aby nedocházelo k průsakům oleje přes labyrintové těsnění mimo převodovou skříň.

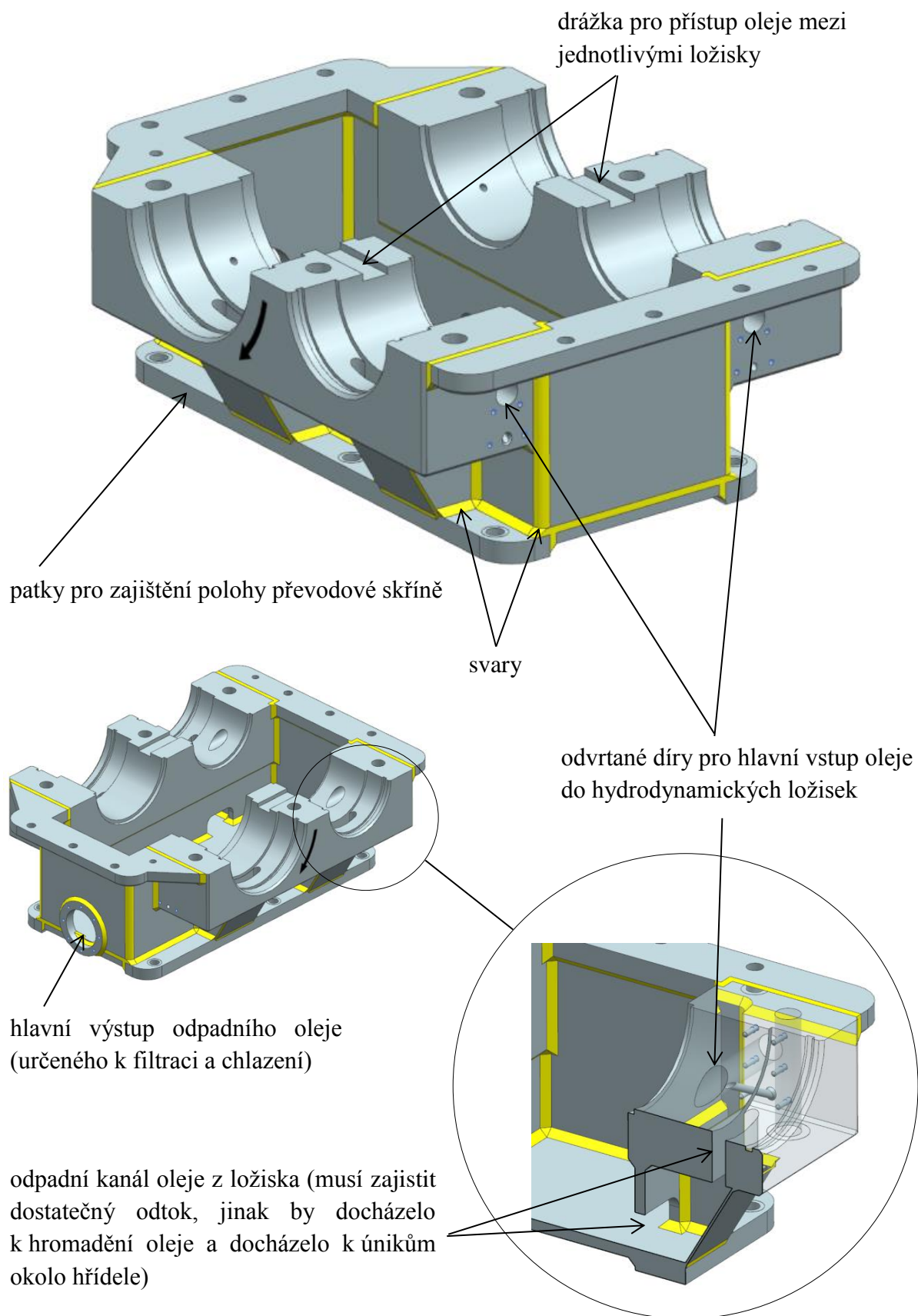
Tento odvod oleje z vnější části ložiska je často řešen prostorem vymezeným dvěma žebry, která jsou překryta tenkým plechem. Do obou míst (zubového záběru a hydrodynamických ložisek) je tedy nezbytně nutný neustálý přísun oleje, proto je nutné odpadní olej z převodové skříně odvádět, filtrovat a chladit, aby se mohl znovu využít pro mazání obou funkčních prvků. Hlavní odvod odpadního oleje z převodové skříně musí být dostatečně velký a umístěný na správné straně spodní části převodové skříně. Vlivem vířivých proudů, vznikajících při vlastní rotaci ozubených kol je totiž olej nepřímo vháněn do hlavního odvodu odpadního oleje.

Abychom zajistili bezproblémový chod převodovky, monitorují se určité hodnoty měřením, např. otáčky hřídelů, vibrace, tlak olejové kapaliny nebo teplota oleje v reakci působící v ložiskové pánvi. Tyto reakce jsou shrnuty v tab. 11. Pro tuto pomocnou převodovku by byla potřeba měřit teplotu na osmi místech. Tímto měřením se předchází případnému zadření ložisek, která jsou finančně nákladná.

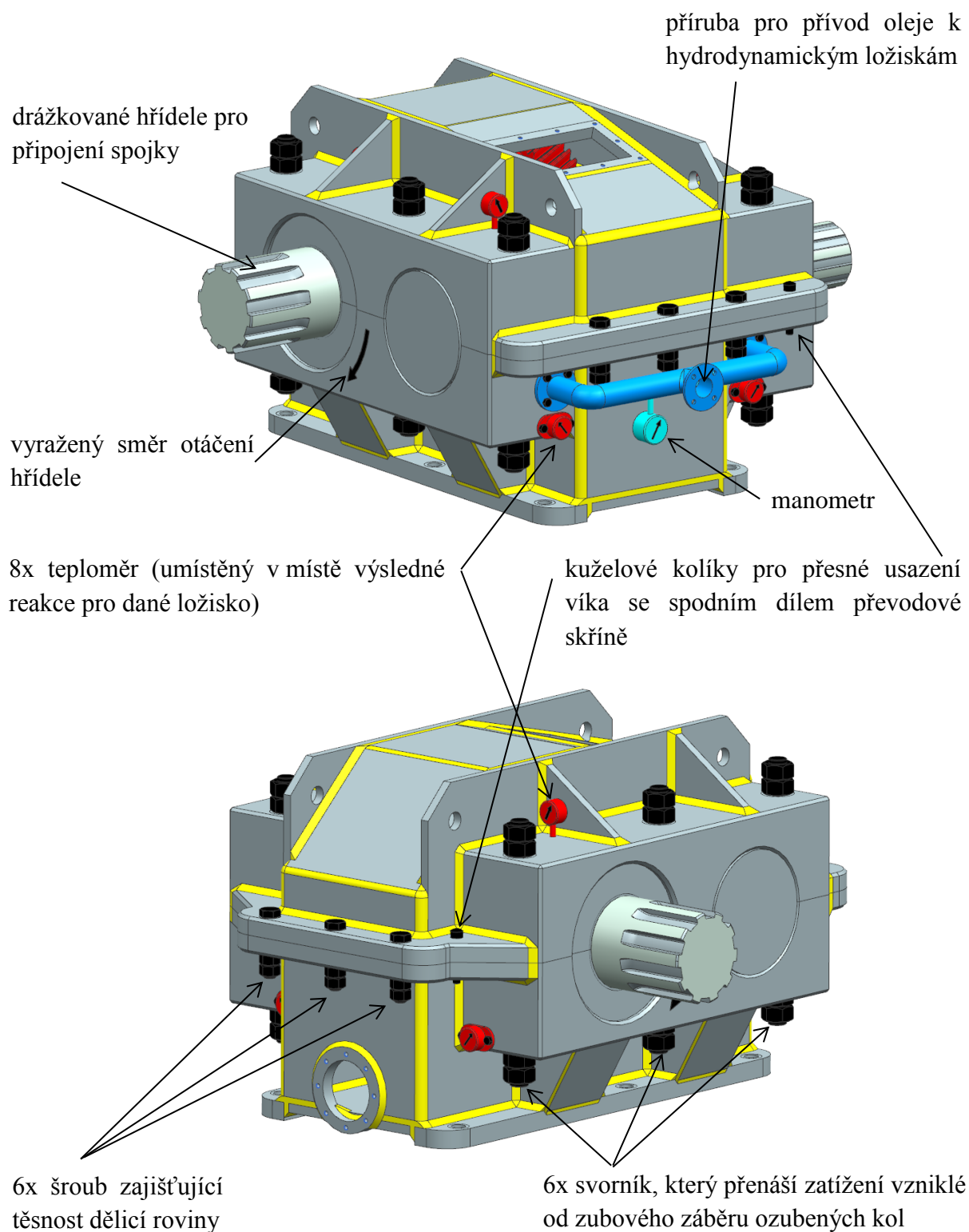
Poslední důležitou komponentou je utěsnění okolo hřídelů. Firma Wikov Gear s.r.o. si vyrábí vlastní dělená labyrintová těsnění, viz obr. 25. Tato speciální těsnění nejsou v přímém kontaktu s hřídelí, jako je tomu např. u gufera. Aby labyrintové těsnění plnilo svoji funkci, je opatřeno odstředivým kuželem, který je také součástí každé hřídele. Vlivem rotace hřídele dochází ke generování odstředivé síly, která působí na olej a má tendenci ho vracet zpět do převodové skříně.



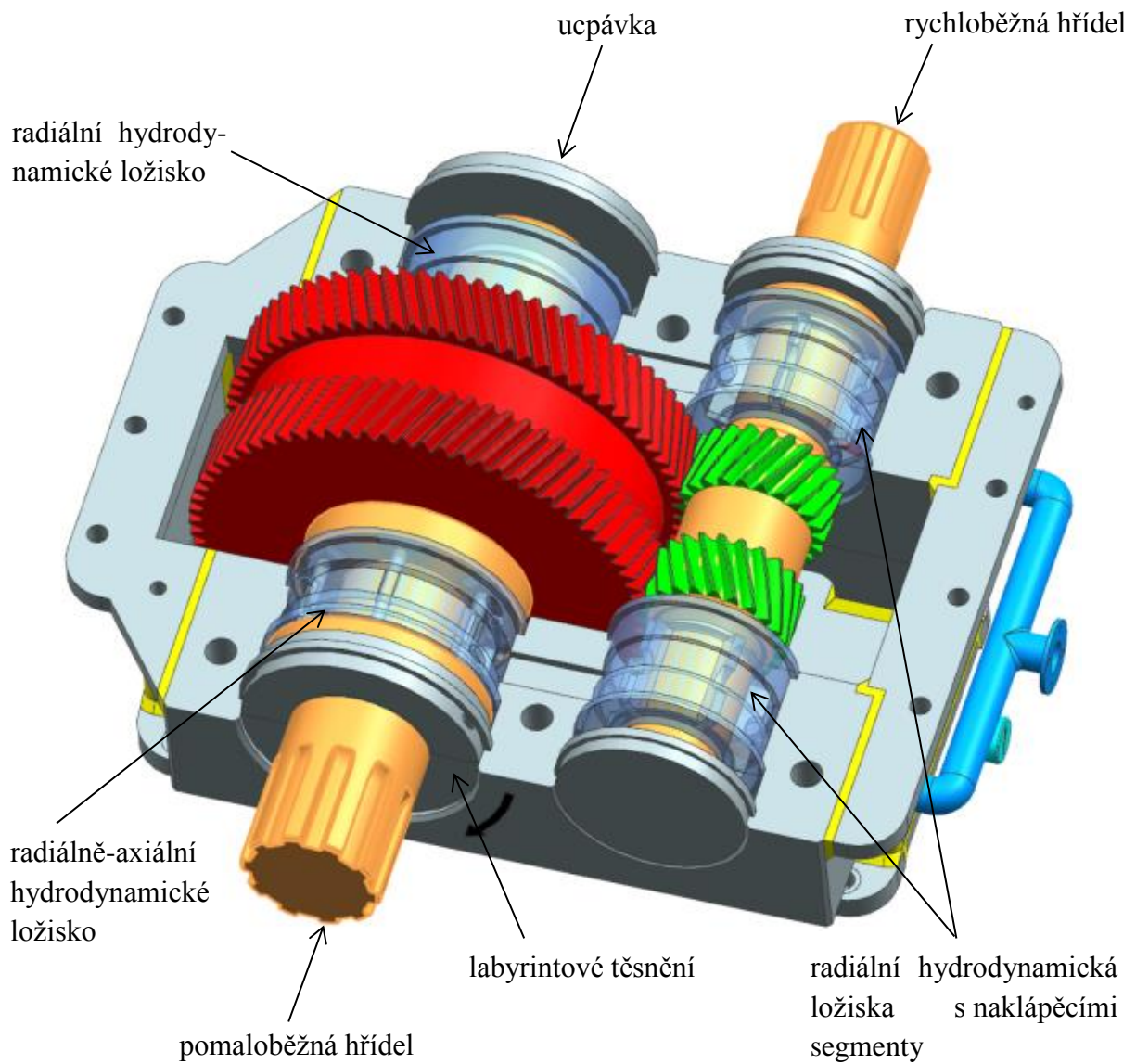
obr. 21 víko převodové skříně



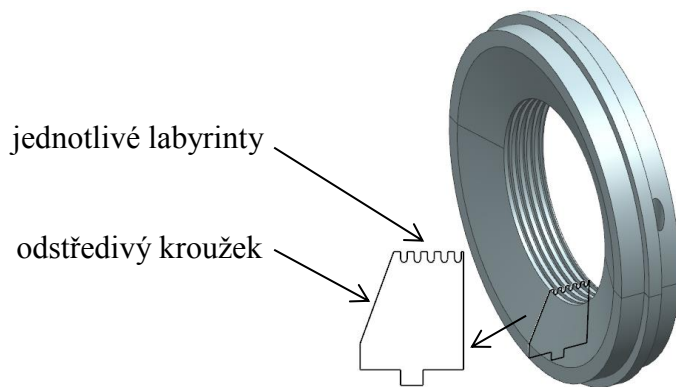
obr. 22 spodní (olejová) část převodové skříně



obr. 23 navržená pomocná převodovka s výměnnými převody

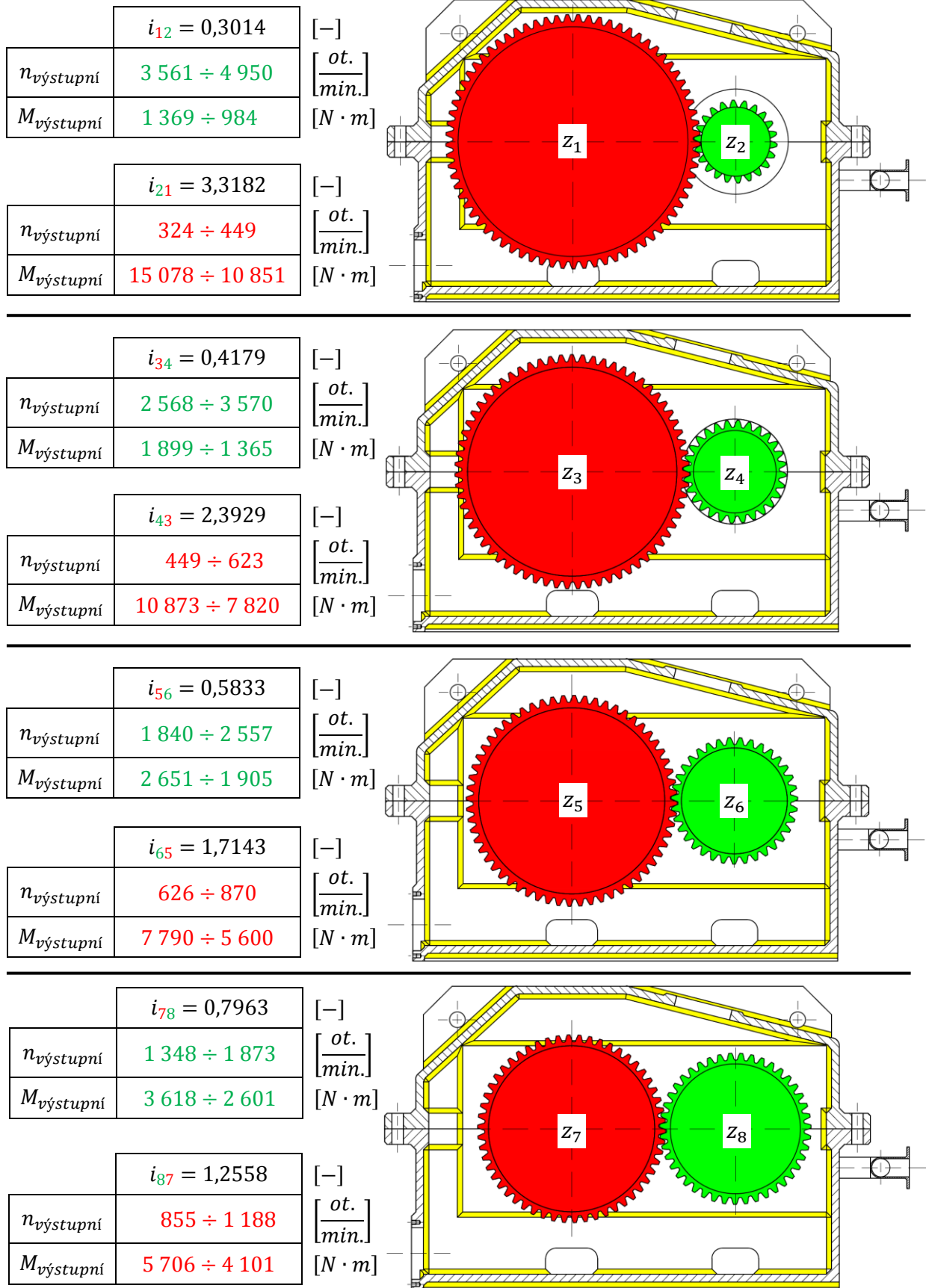


obr. 24 pohled do dělicí roviny navržené pomocné převodovky



obr. 25 labyrintové těsnění

7.1 Rozložení převodů v převodové skříní

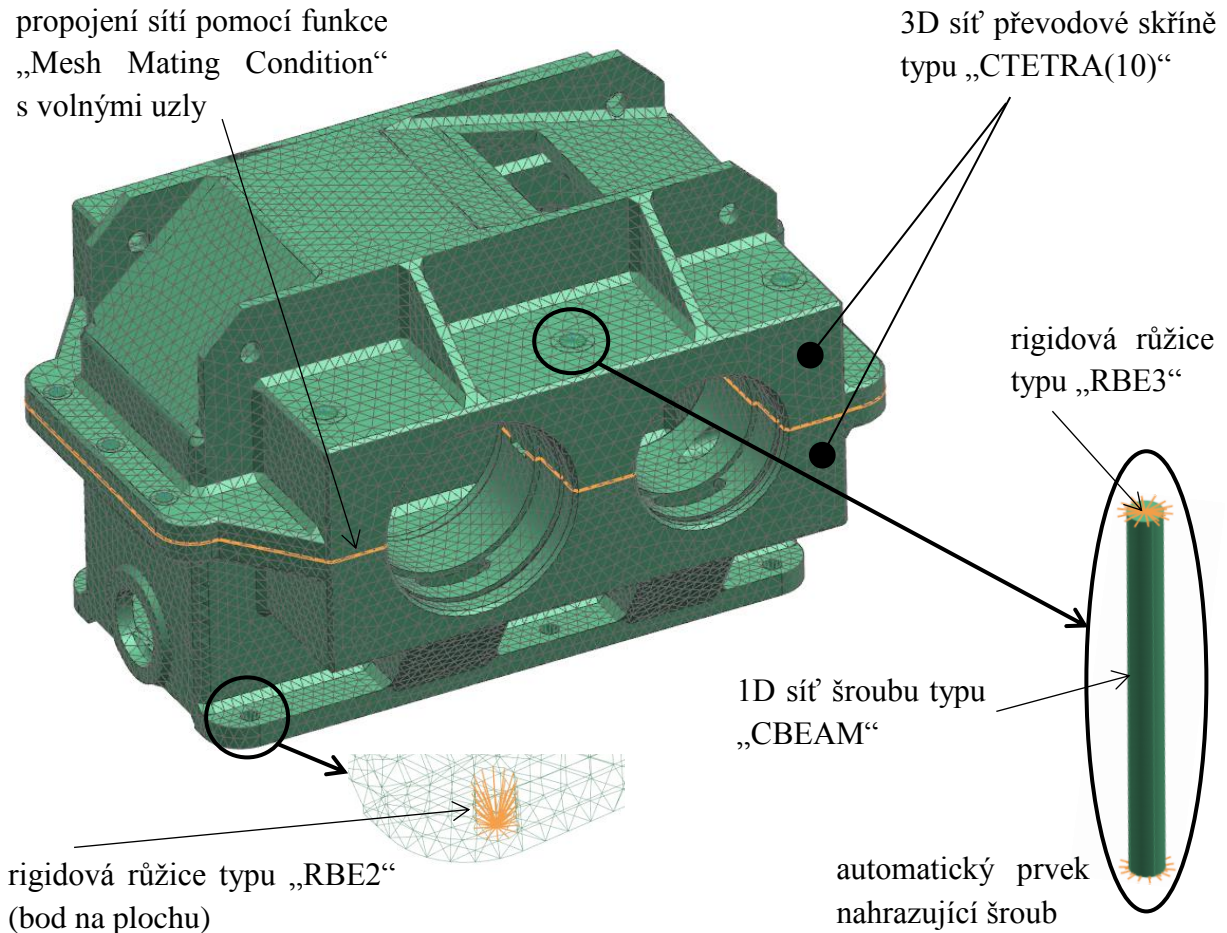


obr. 26 rozložení převodů v převodové skříní

8 MKP analýza převodové skříně

Metoda konečných prvků (MKP) je numerická metoda sloužící k simulaci průběhů napětí, deformací, vlastních frekvencí, proudění tepla, jevů elektromagnetismu, proudění tekutin atd. na vytvořeném fyzikálním modelu. Její princip spočívá v diskretizaci spojitého kontinua do určitého (konečného) počtu prvků, přičemž zjišťované parametry jsou určovány v jednotlivých uzlových bodech. MKP je užívána především pro kontrolu již navržených zařízení, nebo pro stanovení kritického (nejnamáhavějšího) místa konstrukce. Metoda konečných prvků je založena na Lagrangeově principu (těleso je v rovnováze, jestliže celková potenciální energie deformace soustavy je minimální).^[2]

Výhodou této metody je snížení vývojového času a nákladů pro zavedení výroby. Vstupem pro tuto analýzu je navržený model převodové skříně v CAD (počítačem podporované projektování) programu, viz kapitola 7. Pro časové urychlení výpočtu je potřeba většinou model zjednodušit například o malé průměry děr, které neovlivňují námi zkoumanou a předpokládanou oblast maximálního napětí. Na tomto zjednodušeném modelu se dále aplikuje automatická síť konečných prvků, která je hlavní součástí MKP analýzy a jejíž kvalita ovlivňuje přesnost výsledných hodnot. Pro tento model jsem zvolil síť tvořenou čtyřstěny s mezi-uzly „CTETRA(10)“. Jeden takový prvek má celkem 10 uzlových bodů, které jsou základem pro tvorbu lineárních algebraických rovnic. Velikost tohoto elementu pro víko převodové skříně jsem zvolil o velikosti 20 [mm] a pro spodní část o velikosti 18 [mm]. Propojení sítě víka se spodní částí převodové skříně v jeden celek je provedeno pomocí funkce „Mesh Mating Condition“ ve kterém je nastavena vazba mezi jednotlivými uzly na hodnotu „free coincident“. Materiál převodové skříně je z konstrukční oceli typu 11 373, která má mez kluzu $R_e = 220$ [MPa]. V této analýze jsem se zaměřil hlavně na odlehnutí dělicí roviny a na napětí, které bude působit na šrouby spojující tuto dělicí rovinu. Z tohoto důvodu je potřeba pro řešič zvolit síť i pro tyto šrouby. V programu NX jsem využil funkce, která nahrazuje skutečný šroub. Tato funkce nahrazuje šroub poddajným prvkem válcového průřezu o zvoleném průměru a hlavu šroubu s maticí takzvanou rigidovou růžicí, která je uvažována jako absolutně tuhý prvek typu „RBE3“. Pro přesnější výsledky bylo povoleno rigidové růžici propojení k mezi-uzlům u elementů převodové skříně. Pro svorníky přenášející hlavní zatížení je zvolen šroub M30. Ostatní šrouby zajišťující těsnost v dělicí rovině jsou M20. Poslední přípravou před zadáním okrajových podmínek byla aplikace 1D sítě typu „bod na plochu“ v dírách sloužícím pro ustavení převodové skříně v požadované poloze. Tato 1D síť je zvolena jako absolutně tuhý prvek typu „RBE2“ a slouží k následnému zavedení potřebné okrajové podmínky nutné pro výpočet. Na obr. 27 je zobrazen celý model s vytvořenou sítí konečných prvků, na který se následně budou aplikovat okrajové podmínky.

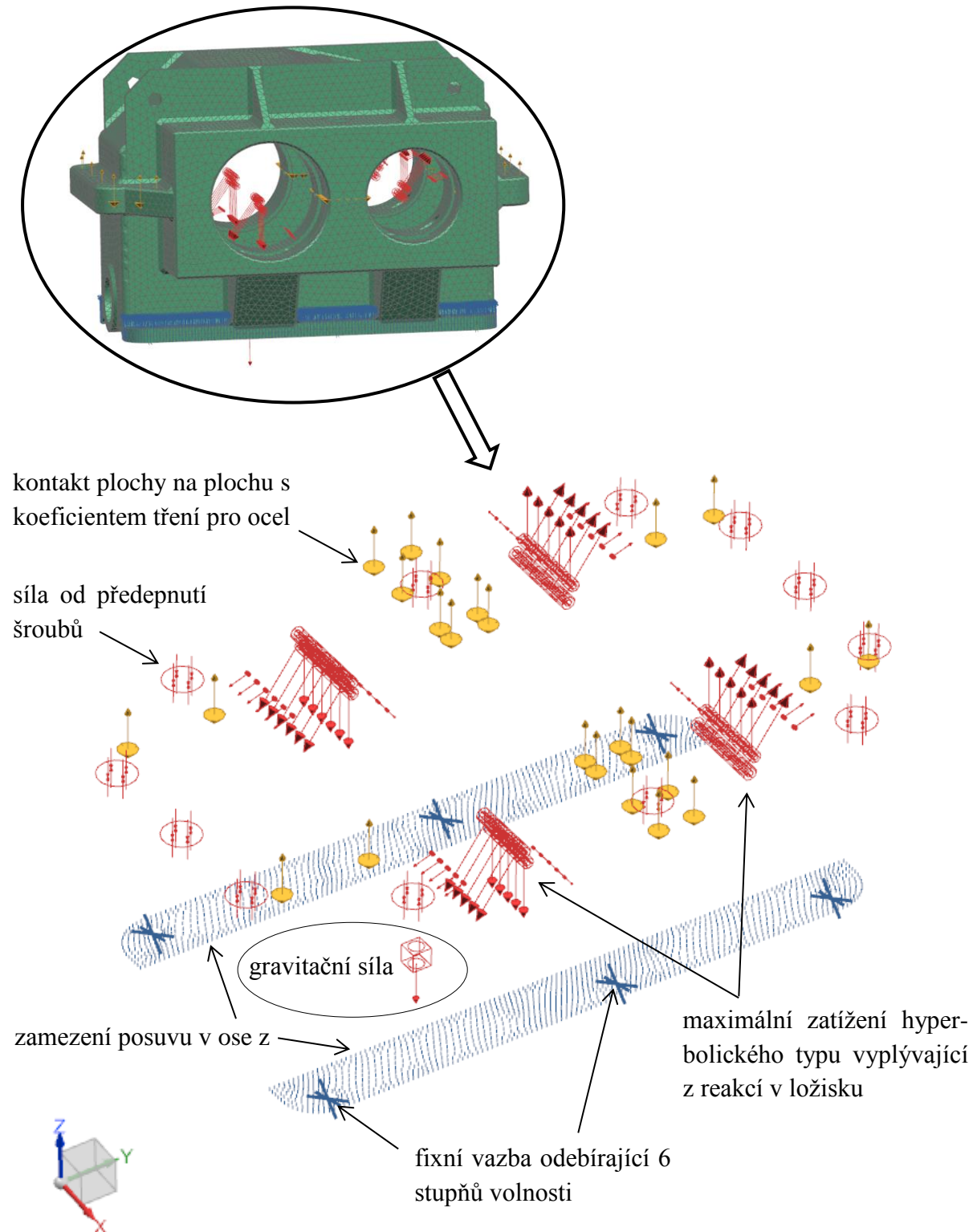


obr. 27 model s vytvořenou sítí konečných prvků

8.1 Okrajové podmínky

Okrajové podmínky potřebné pro výpočet MKP analýzy je potřeba zvolit tak, abychom se přiblížili co nejvíce skutečným podmínkám při provozu převodové skříně. Špatnou volbou okrajových podmínek dochází ke zkresleným nebo nesmyslným výsledkům, které se snažíme eliminovat. Převodová skříň je ustavena v prostoru fixní vazbou odebírající 6 stupňů volnosti za jednotlivé body, nacházející se v dírách patek sloužících pro ustavení. Tyto body byly vytvořeny v minulé kapitole. Dále je zamezen posuv v ose z na spodních plochách patek, které zjednodušeně nahrazují pevný základ, na kterém je převodovka ustavena. Pro zjištění reálného chování v místě dělicí roviny byla využita kontaktní funkce „plocha na plochu“, která mnohonásobně prodlužuje celkový výpočetní čas. V této funkci je nutné zadat statický součinitel tření jednotlivých (ocelových) ploch. Tento součinitel byl zvolen pro daný materiál ze strojních tabulek s hodnotou 0,15 [–]. Posledními okrajovými podmínky je aplikace všech sil působících na převodovku. Pro větší stroje je uvažováno s gravitační silou, která může ovlivnit celkové výsledky. V dělicí rovině se nachází celkem 12 kusů šroubů, které přenášejí zatížení nebo slouží k jejímu utěsnění. Všechny tyto šrouby jsou předepjaty, aby nedocházelo k odlehnutí dělicí roviny a následným netěsnostem. Předepnutím se dále snižuje i cyklické namáhání šroubů. Sílu pro předepnutí svorníků jsem spočetl na orientační hodnotu 18,5 [kN]. Ostatní šrouby zajišťující těsnost v dělicí rovině byli předepjaty silou 15 [kN].

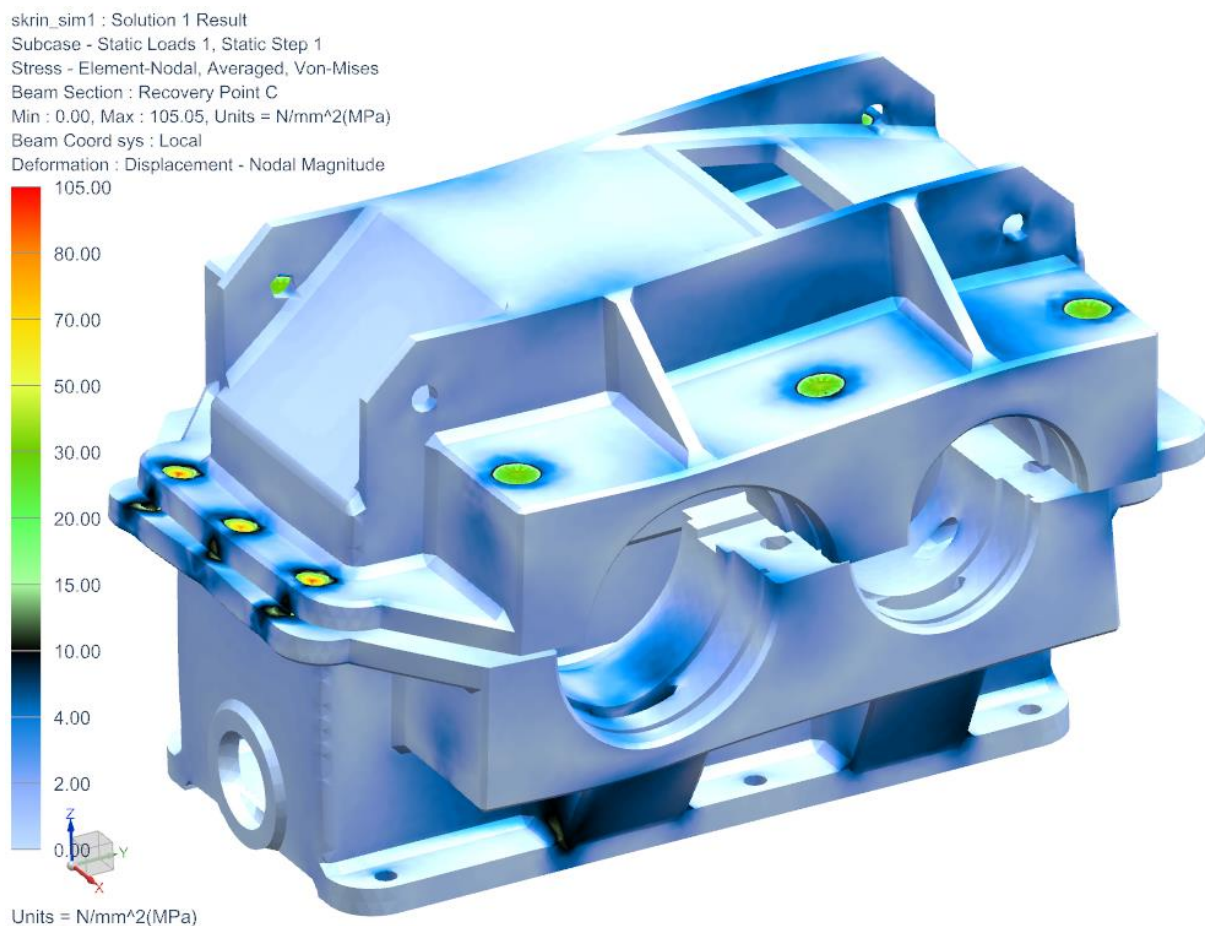
Hlavní zatěžující silou pro převodovku jsou výsledné reakce vznikající v místě hydrodynamických ložisek, viz tab. 11. Z těchto sil byla vybrána maximální síla, která nastane při využití převodu i_{21} . Jednotlivé směry a hodnoty sil působících v místě hydrodynamických ložisek byly aplikovány pomocí speciální funkce „bearing“, která je v nabídce programu NX. Výhodou použití této funkce je možnost volby parabolického rozložení každé síly, která se přibližuje skutečnému zátěžnému stavu. Jednotlivé okrajové podmínky jsou vidět na obr. 28.



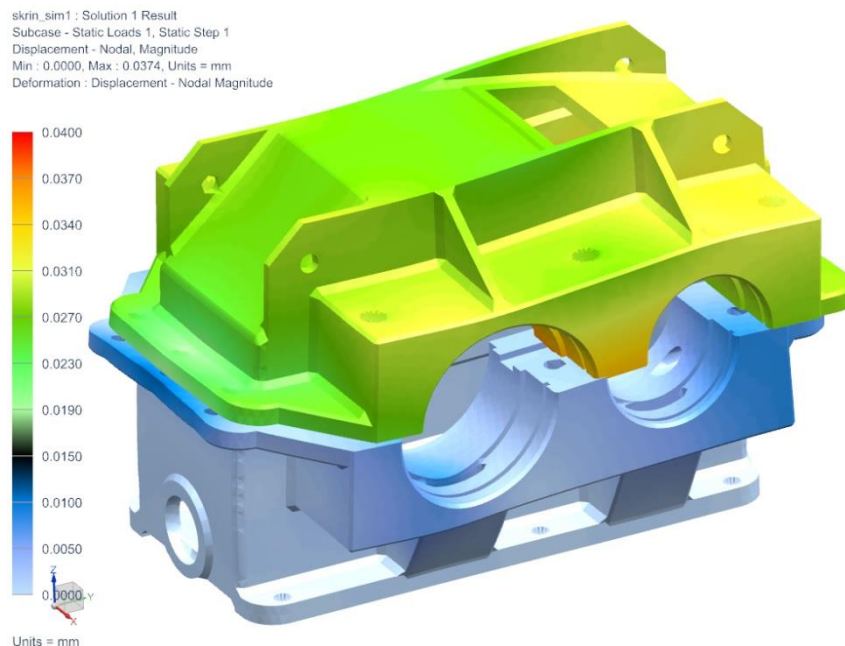
obr. 28 okrajové podmínky potřebné pro analýzu

8.2 Výsledky analýzy

Výsledky analýz jsou zobrazeny na obr. 29 - obr. 31. Pro čitelné zobrazení toho, jak se model převodové skříně chová při zatížení, je zobrazení modelu v 5 [%] měřítku deformace z modelu. Z obr. 30 je patrná deformace převodové skříně při maximálním možném zátěžném stavu. Jak je patrné z tohoto obrázku, nedochází pouze k odlehnutí víka od spodní části převodové skříně, ale dochází také k jejímu smýkání ve směru osy y. To je způsobeno tím, že výsledné reakce působí pod úhlem cca 22 [°] od osy z v rovině yz. Výsledné hodnoty posuvů jsou v řádech setin milimetru, které ve skutečnosti budou ještě nižší vlivem vložených hydrodynamických ložisek. Na obr. 29 je zobrazen průběh redukovaného napětí dle hypotézy HMM. Z výsledků je patrné, že maximální napětí v převodové skříně je cca 25 [MPa]. Při zvoleném materiálu převodové skříně z konstrukční oceli 11 373, která má mez kluzu $R_e = 220$ [MPa], vychází koeficient bezpečnosti cca 8 [–]. Nejvíce namáhaným prvkem převodové skříně jsou jednotlivé šrouby. Redukované napětí ve šroubech se pohybuje v rozmezí od 30 do 95 [MPa] v závislosti na poloze jednotlivých šroubů. Maximální napětí s hodnotou 105 [MPa] je způsobeno vlivem lokální nepřesnosti sítě.



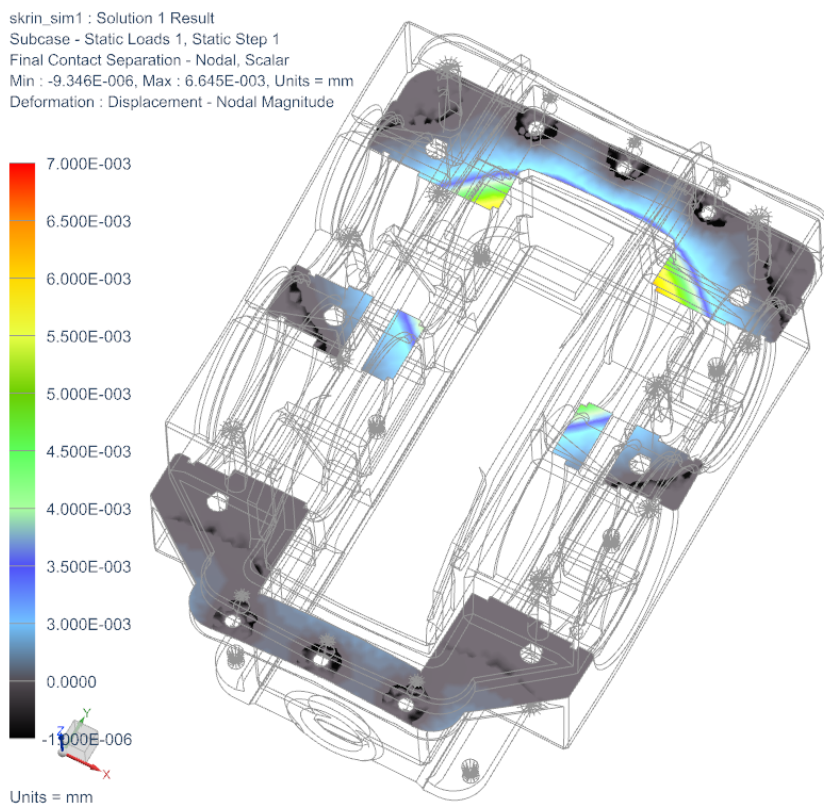
obr. 29 průběh redukovaného napětí v převodové skříně dle hypotézy HMM



obr. 30 deformace převodové skříně

8.2.1 Odlehnutí ploch v dělicí rovině

Na obr. 31 je zobrazeno odlehnutí víka od spodní části převodové skříně. Z obrázku je patrné, že k největšímu odlehnutí dochází právě v místech, kde působí výsledné reakce v uložení hřídelů do vrchní části, tj. víka převodové skříně. Z výsledků lze snadno rozeznat, že při působení této maximální zátěžné síly bude převodová skříně při dodržení předepnutí jednotlivých šroubů 100 [%] utěsněna.



obr. 31 odlehnutí dělicí roviny při maximálním zatížení

9 Technicko-ekonomické zhodnocení

Technicko-ekonomické zhodnocení procesu slouží ke stanovení nákladů, které jsou potřebné k uskutečnění výroby zadané součásti. Technické zhodnocení je potřebné k určení parametrů výroby a tím zjištění, zda je součást vyrobitelná. Ekonomické zhodnocení je zapotřebí především ke stanovení prodejní ceny a tržeb firmy. K tomuto zhodnocení poslouží tab. 15, kde se stanoví jednotlivé reálné varianty výroby, a posouzením vlivu jednotlivých faktorů získáme nejlepší variantu.

Každý sloupec tabulky nám dává na výběr způsoby výroby převodovky při zachování dané funkce. Variant výroby může být několik, ale dle zadání diplomové práce je většina těchto parametrů předem stanovena.

Varianta A zobrazuje požadavky na výrobu převodovky dané firmou Wikov Gear s.r.o. Variantu B bych zvolil při požadavku na levnější výrobu, kdy bych hydrodynamická ložiska změnil za valivá, která jsou ekonomičtější, ale snižují účinnost pomocné převodovky. Změna ložiska má také za následek zjednodušení převodové skříně a snížení požadavku na mazání ložisek.

převodová skříně	svařenec	odlitek	
typ ozubení	čelní ozubení s dvojitě šikmými zuby	čelní ozubení přímé	čelní zubení se šikmými zuby
způsob mazání ozubeného převodu	rozstříkem (broděním)	přímým vstříkem do zubového záběru	olejovou mlhou
změna převodu	ručně řaditelná	mechanická výměna převodů	
ložiska	hydrostatická	hydrodynamická	valivé
pracovní prostředí	vnitřní	venkovní	
zatížitelnost	trvalý provoz	přerušovaný provoz	
spoj ozubeného kola s hřídelí	nalisování	výroba z jednoho kusu	drážkový spoj
konec vstupního a výstupního členu	spoj perem	drážkový spoj	kuželový svěrný spoj

tab. 15 stanovení parametrů převodovky

Firma Wikov Gear s.r.o. pro tuto práci poskytla skutečné ceny jednotlivých hlavních dílů vyráběné převodovky, viz tab. 16, která se podobá svou velikostí a přenášeným výkonem pomocné převodovce zpracované v této práci. Výrobní ceny uvažují stejné s jediným rozdílem, kterým je počet kusů pomaloběžné a rychloběžné hřídele s ozubením pro možnost změny převodového poměru. Pro tuto pomocnou převodovku bylo zapotřebí použít 4 pomaloběžné a rychloběžné hřídele. Výrobní cenu celé pomocné převodovky varianty A odhaduji přibližně na 1 862 700 [Kč].

převodová skříň	192 800	[Kč]
rychloběžná hřídel s pastorkem	70 078	[Kč]
pomaloběžná hřídel s ozubeným kolem	134 196	[Kč]
2x radiální hydrodynamické ložisko s naklá-pěcími segmenty (pro rychloběžnou hřídel)	2x 95 000	[Kč]
radiální hydrodynamické ložisko (pro pomaloběžnou hřídel)	30 000	[Kč]
radiálně-axiální hydrodynamické ložisko (pro pomaloběžnou hřídel)	35 000	[Kč]
celková cena převodovky	1 249 878	[Kč]

tab. 16 výrobní ceny dle firmy Wikov Gear s.r.o.

Aby bylo možné porovnat náklady potřebné na výrobu pomocné převodovky varianty B, požádal jsem firmu SKF o zaslání cenové nabídky na různé druhy ložisek viz tab. 17. Tyto druhy ložisek jsem stanovil po předběžných výpočtech a všechna vydrží maximální namáhání stanovené v tab. 11. Výrobní cenu této pomocné převodovky varianty B odhaduji přibližně na 1 700 000 [Kč].

typ válečkového ložiska SKF	cena bez DHP	
NU 326 ECP	22 474	[Kč]
NJ 326 ECJ	38 475	[Kč]
NU 2226 ECP	15 423	[Kč]
NU 2228 ECML	35 662	[Kč]
NU 2326 ECML	70 836	[Kč]
NU 2320 ECML	35 599	[Kč]
NJ 2320 ECML	30 154	[Kč]

tab. 17 ceny ložisek firmy SKF

10 Dynamické zatížení převodové skříně

Převodová skříně je vystavena dynamickým účinkům sil vznikajícím z rotace hřídelí a ozubených kol. Při tomto dynamickém namáhání může docházet k rezonančnímu stavu převodové skříně nebo hřídelí. Tento stav je nepříjemnou skutečností každého točivého stroje. Způsobuje vysoké hodnoty deformací jednotlivých prvků a je potřeba se těmto rezonančním stavům vyhnout. Tyto rezonanční stavy nastávají tehdy, jeli budicí frekvence rovna vlastní frekvenci dané součásti. Budicí frekvence je přímo úměrná otáčkám jednotlivých hřídelí a ozubených kol. Jelikož tato pomocná převodovka může pracovat ve velkém rozsahu otáček, nemělo by docházet ke stavu rezonance v celém rozsahu otáček. Vlastní frekvence a příslušné tvary kmitů lze zjistit například výpočetní technikou. Jelikož převodovka a tudíž i hydrodynamická ložiska pracují ve velkém rozsahu otáček a různých zatěžujících spektrech, nelze přesně určit jednotlivé tuhosti a útlumy pro jednotlivá hydrodynamická ložiska. Tyto měnící se tuhosti a útlumy jsou vstupním a také hlavním parametrem pro zjištění skutečných vlastních frekvencí. Stanovení správných vlastních frekvencí se vymyká rozsahu této diplomové práce a jejich určení by v tomto případě bylo velice obtížné.

Jednotlivé rezonanční stavy lze také zjistit na již vyrobené převodovce za jejího provozu. Toho lze dosáhnout měřením na předpokládaných kritických místech nebo místech, kde je potřeba diagnostiky kvůli možné predikci poruchy. Pokud by na této pomocné převodovce docházelo k rezonančnímu stavu, bylo by jediným řešením převodovou skříně dodatečně vyztužit pomocným vhodně umístěným žebrem nebo se vyhnout kritickým otáčkám, způsobujícím rezonanční stav. Vzhledem ke zvoleným rozměrům jednotlivých hřídelů a zvolené tloušťky plechů pro výrobu převodové skříně můžeme předpokládat, že k rezonančním stavům nebude docházet.

11 Závěr

V této diplomové práci jsem se zabýval návrhem pomocné převodovky pro zkušebnu, kterou by chtěli využívat ve firmě Wikov Gear s.r.o. pro testování průmyslových převodovek. Vzhledem k jednoznačnému zadání jsem neměl příliš velkou možnost výběru různých konstrukčních variant. V práci jsem se tedy zaměřil hlavně na praktické výpočty a snažil se je shrnout do praktických grafů a tabulek, které popisují provozní stavy pomocné převodovky. Na základě těchto údajů jsem navrhl a vymodeloval univerzální převodovou skříně s ostatními převody a příslušenstvím. Pomocí simulačního softwaru jsem celý model otestoval na nejvyšší zátěžný stav. Zajímavým výsledkem je zobrazení odlehnutí dělicí roviny, které může vést při špatném návrhu k netěsnostem převodové skříně a úniku oleje, který je vždy nežádoucí. Tuto práci hodnotím jako velice zajímavou, protože požadované převody nejsou z finanční náročnosti řaditelné, ale musí se vždy pro testování na daný stav mechanicky vyměnit. V této práci jsem se hlouběji ponořil do problematiky návrhu převodovek a naučil se zpracování ve výpočtovém softwaru KISSOFT. Díky tomu se prohloubily moje zkušenosti a vědomosti v této oblasti konstrukcí.

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Siemens NX v. 8.5

Microsoft Office 2010

AutoCAD 2007

KISSOFT - release 03-2012F

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Příloha 1: výsledky ozubených převodů z programu KISSOFT

(pouze ukázka zbytek se nachází na přiloženém CD)

----- KISSsoft - Release 03-2012F -----
KISSsoft academic license for Uni Pilsen

----- Project -----
Name : prevodovka_zkusebna

----- File -----
Name : i12
Changed by : jirisuch on: 14.03.2014 at: 18:03:25

Important hint: At least one warning has occurred during the calculation:

1-> The circumferential speed is very high (27.1517 m/s)!
You have to take adequate action to
guarantee proper lubrication.

2-> Notice to gear 1:
NOT POSSIBLE TO MEASURE BASE TANGENT LENGTH!
The width of the gear is too small, hence the tooth thickness too big,
so that the required length for the measurement exceed the face width.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 --
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	1073.0	3560.4
Torque (Nm)	[T]	4541.0	1368.5
Application factor	[KA]		1.20
Required service life	[H]	20000.00	
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 --
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	73	22
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 --
Surface hardness		HRC 56	HRC 56
Fatigue strength. tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofpP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in) [Ca]	3.4	3.4
-----------------	--------------------------------	-----	-----

Lubrication type

oil injection lubrication

Type of oil

Oil: ISO-VG 46

Lubricant base

Mineral-oil base

Kinem. viscosity oil at 40 °C (mm²/s)

[nu40]

46.00

Kinem. viscosity oil at 100 °C (mm²/s)

[nu100]

6.70

FZG test A/8.3/90 (

ISO 14635-1:2006)

[FZGtestA]

12

Specific density at 15 °C (kg/dm³)

[roOil]

0.880

Oil temperature (°C)

[TS]

70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.301	
Gear ratio	[u]	3.318	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	22.122	
	[alfwt.e/i]	22.146 / 22.122	
Working pressure angle at normal section (°)	[alfwn]	20.219	
Helix angle at operating pitch circle (°)	[betaw]	25.037	
Base helix angle (°)	[betab]	23.399	
Reference centre distance (mm)	[ad]	314.463	
Sum of profile shift coefficients	[Summexi]	0.0900	
Profile shift coefficient	[x]	-0.1753	0.2654
Tooth thickness (Arc) (module)	[sn*]	1.4432	1.7640
Tip alteration (mm)	[k*mn]	-0.003	-0.003
Reference diameter (mm)	[d]	483.280	145.646
Base diameter (mm)	[db]	448.466	135.154
Tip diameter (mm)	[da]	493.170	160.824
(mm)	[da.e/i]	493.170 / 492.920	160.824 / 160.814
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.250	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	493.170	160.824
(mm)	[dFa.e/i]	493.170 / 492.920	160.824 / 160.814
Active tip diameter (mm)	[dNa.e/i]	493.170 / 492.920	160.824 / 160.814
Operating pitch diameter (mm)	[dw]	484.105	145.895
(mm)	[dw.e/i]	484.185 / 484.105	145.919 / 145.895
Root diameter (mm)	[df]	466.176	133.830
Generating Profile shift coefficient	[xE.e/i]	-0.2051 / -0.2188	0.2436 / 0.2322
Manufactured root diameter with xE (mm)	[df.e/i]	465.818 / 465.654	133.569 / 133.432
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.876 / 1.631	1.818 / 1.679
Active root diameter (mm)	[dNf]	472.914	138.909
(mm)	[dNf.e/i]	473.007 / 472.914	139.115 / 138.909
Root form diameter (mm)	[dFf]	469.663	137.998

	(mm)		[dFf.e/i]	469.379 / 469.249	137.858 / 137.786
Reserve (dNf-dFf)/2 (mm)			[cF.e/i]	1.879 / 1.767	0.665 / 0.526
Addendum (mm)		[ha = mn * (haP**x)]		4.945	7.589
(mm)		[ha.e/i]	4.945 / 4.820		7.584
Dedendum (mm)		[hf = mn * (hfP*-x)]		8.552	5.908
(mm)		[hf.e/i]	8.731 / 8.813		6.107
Roll angle at dFa (°)		[xsi_dFa.e/i]	26.212 / 26.135		36.952 / 36.944
Roll angle to dNa (°)		[xsi_dNa.e/i]	26.212 / 26.135		36.952 / 36.944
Roll angle to dNf (°)		[xsi_dNf.e/i]	19.212 / 19.175		13.972 / 13.600
Roll angle at dFf (°)		[xsi_dFf.e/i]	17.700 / 17.644		11.517 / 11.361
Tooth height (mm)		[H]		13.497	13.497
Virtual gear no. of teeth		[zn]		95.628	28.820
Normal tooth thickness at tip cyl. (mm)		[san]		4.925	3.970
(mm)		[san.e/i]	4.894 / 4.732		3.873 / 3.813
Normal spacewidth at root cylinder (mm)		[efn]		4.601	0.000
(mm)		[efn.e/i]	4.632 / 4.647		0.000 / 0.000
Max. sliding velocity at tip (m/s)		[vga]		5.546	7.817
Specific sliding at the tip		[zetaa]		0.481	0.481
Specific sliding at the root		[zetaf]		-0.927	-0.927
Sliding factor on tip		[Kga]		0.204	0.287
Sliding factor on root		[Kgf]		-0.287	-0.204
Pitch on reference circle (mm)		[pt]			20.798
Base pitch (mm)		[pbt]			19.300
Transverse pitch on contact-path (mm)		[pet]			19.300
Lead height (mm)		[pz]		3255.935	981.241
Axial pitch (mm)		[px]			44.602
Length of path of contact (mm)		[ga, e/i]		27.542 (27.542 / 27.094)	
Length T1-A, T2-A (mm)		[T1A, T2A]	75.042 (75.042/75.189)		43.582 (43.582/43.573)
Length T1-B (mm)		[T1B, T2B]	83.284 (83.284/82.983)		35.340 (35.340/35.779)
Length T1-C (mm)		[T1C, T2C]	91.153 (91.153/91.259)		27.471 (27.471/27.503)
Length T1-D (mm)		[T1D, T2D]	94.342 (94.342/94.489)		24.282 (24.282/24.273)
Length T1-E (mm)		[T1E, T2E]	102.584 (102.584/102.283)		16.040 (16.040/16.479)
Length T1-T2 (mm)		[T1T2]		118.624 (118.624 / 118.762)	
Diameter of single contact point B (mm)		[d-B]	478.401 (478.401/478.191)		152.520 (152.520/152.929)
Diameter of single contact point D (mm)		[d-D]	486.543 (486.543/486.657)		143.615 (143.615/143.609)
Addendum contact ratio		[eps]	0.592 (0.592/ 0.571)		0.835 (0.835/ 0.833)
Minimal length of contact line (mm)		[Lmin]			97.027
Transverse contact ratio		[eps_a]			1.427
Transverse contact ratio with allowances		[eps_a.e/m/i]		1.427 / 1.415 / 1.404	
Overlap ratio		[eps_b-beH (eps_b-b)]			1.569 (3.139)
Total contact ratio		[eps_g]			2.997 (4.566)
Total contact ratio with allowances		[eps_g.e/m/i]		2.997/2.985/2.973	(4.566/4.554/4.543)

2. FACTORS OF GENERAL INFLUENCE

	----- GEAR 1 -----	GEAR 2 --
Nominal circum. force at pitch circle (N)		
	[Ft]	18792.4
Axial force (N)	[Fa]	0.0
Radial force (N)	[Fr]	7547.0
Normal force (N)	[Fnorm]	22065.9
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	134.23
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	18760.4
Axial force (N)	[Faw]	0.0
Radial force (N)	[Frw]	7626.3
Circumferential speed pitch d.. (m/sec)	[v]	27.15
Running-in value (µm)	[yp]	0.8
Running-in value (µm)	[yf]	0.8
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	13.146
Meshing stiffness (N/mm/µm)	[cg]	17.356
Reduced mass (kg/mm)	[mRed]	0.07223
Resonance speed (min-1)	[nE1]	2028
Nominal speed (-)	[N]	0.529
Subcritical range		
Running-in value (µm)	[ya]	0.8
Bearing distance l of pinion shaft (mm)	[l]	336.000
Distance s of pinion shaft (mm)	[s]	16.800
Outside diameter of pinion shaft (mm)	[dsh]	132.400
Load according to figure 6.8, DIN 3990-1:1987 [-]		4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)		

Coefficient K' according figure 6.8, DIN 3990-1:1987 [K']		-1.00	
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]	4.25	
from deformation of shaft (µm)	[fsh*B1]	2.37	
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (µm)	[fma*B2]	10.00	
Tooth trace deviation, theoretical (µm)	[Fbx]	5.00	
Running-in value (µm)	[yb]	0.8	
Dynamic factor	[KV]	1.248	
Face load factor - flank	[KHb]	1.184	
- Tooth root	[KFb]	1.146	
- Scuffing	[KBb]	1.184	
Transverse load factor - flank	[KHα]	1.212	
- Tooth root	[KFα]	1.212	
- Scuffing	[KBα]	1.212	
Helical load factor scuffing	[Kbg]	1.283	
Number of load cycles (in mio.)	[NL]	1287.600	4272.491

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	GEAR 2 --
Tooth form factor	[YF]	1.33	1.18
Stress correction factor	[YS]	2.25	2.42
Working angle (°)	[alfFen]	19.42	20.38
Bending lever arm (mm)	[hF]	6.68	5.56
Tooth thickness at root (mm)	[sFn]	13.47	13.00
Tooth root radius (mm)	[roF]	2.43	2.29
(hF* = 1.113/0.927 sFn* = 2.245/2.166 roF* = 0.405/0.381 dsFn = 468.04/135.57 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm²)	[sigF0]	53.12	50.66
Tooth root stress (N/mm²)	[sigF]	110.47	105.36
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.002	1.003
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.950	0.950
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm²)	[sigFG]	702.64	703.09
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	501.89	502.20
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	6.36	6.67
Transmittable power (kW)	[kWRating]	2318.11	2432.11

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	GEAR 2 --
Zone factor	[ZH]		2.290
Elasticity coefficient (N ^{0.5} /mm)	[ZE]		189.812
Contact ratio factor	[Zeps]		0.837
Helix angle factor	[Zbet]		0.952
Effective facewidth (mm)	[beff]		70.00
Nominal flank pressure (N/mm²)	[sigH0]		379.34
Surface pressure at operating pitch circle (N/mm²)	[sigHw]		555.83
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	555.83	555.83
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	1.030	1.030
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000

	[ZL*ZV*ZR*ZNT]	0.952	0.952
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm ²)	[sigHG]	1161.54	1161.54
Permissible surface pressure (N/mm ²) [sigHP=sigHG/SHmin]		1161.54	1161.54
Safety for surface pressure at operating pitch circle			
	[SHw]	2.09	2.09
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	2228.22	2228.22
Safety for stress at single tooth contact			
	[SHBD=sigHG/sigH]	2.09	2.09
(Safety regarding nominal torque)	[(SHBD)^2]	4.37	4.37

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	3.40	3.40
Optimal tip relief (µm)	[Ceff]	6.19	
Effective facewidth (mm)	[beff]	70.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	369.636	
Pressure angle factor (eps1: 0.592, eps2: 0.835)	[Xalfbet]	0.990	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	92.78	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	40.40	
Scuffing temperature (°C)	[theS]	469.40	
Coordinate gamma (point of highest temp.)	[Gamma]	0.286	
[Gamma.A]= -0.177 [Gamma.E]= 0.125			
Highest contact temp. (°C)	[theB]	133.18	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} *mm)	[XM]	50.058	
Geometry factor	[XB]	0.135	
Load sharing factor	[XGam]	1.000	
Dynamic viscosity (mPa*s)	[etaM]	6.63	
Coefficient of friction	[mym]	0.058	
Required safety	[SBmin]	2.000	
Safety factor for scuffing (flash-temp)	[SB]	6.320	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	85.68	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	18.67	
Integral scuffing temperature (°C)	[theSint]	469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} *mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.270	
Dynamic viscosity (mPa*s)	[etaOil]	12.31	
Averaged coefficient of friction	[mym]	0.053	
Geometry factor	[XBE]	0.259	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.026	
Integral tooth flank temperature (°C)	[theint]	113.69	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	4.129	
Safety referring to transferred torque	[SSL]	9.142	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 -----
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.095 / -0.145
Number of teeth spanned	[k]	11.000	4.000
Base tangent length (no backlash) (mm)	[Wk]	193.379	65.529
Actual base tangent length ('span') (mm)	[Wk.e/i]	193.257 / 193.200	65.440 / 65.393
Diameter of contact point (mm)	[dMWk.m]	482.256	147.889

> Base tangent length Gear 1 is not measurable (Gear too thin)

Theoretical diameter of ball/pin (mm)	[DM]	10.027	10.702
Eff. Diameter of ball/pin (mm)	[DMeff]	10.500	11.000
Theor. dim. centre to ball (mm)	[MrK]	248.218	82.429
Actual dimension centre to ball (mm)	[MrK.e/i]	248.045 / 247.965	82.327 / 82.274
Diameter of contact point (mm)	[dMMr.m]	481.900	149.069
Diametral measurement over two balls without clearance (mm)	[MdK]	496.324	164.859
Actual dimension over balls (mm)	[MdK.e/i]	495.978 / 495.817	164.655 / 164.547
Diametral measurement over rolls without clearance (mm)	[MdR]	496.437	164.859
Actual dimension over rolls (mm)	[MdR.e/i]	496.090 / 495.930	164.655 / 164.547
Dimensions over 3 rolls without clearance (mm)	[Md3R]	496.437	0.000
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	496.090 / 495.930	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)	['sn]	8.659	10.577
Actual chordal tooth thickness (mm)	['sn.e/i]	8.529 / 8.469	10.482 / 10.432
Reference chordal height from da.m (mm)	[ha]	4.914	7.745
Tooth thickness (Arc) (mm)	[sn]	8.659	10.584
(mm)	[sn.e/i]	8.529 / 8.469	10.489 / 10.439
Backlash free center distance (mm)	[aControl.e/i]	314.693	/314.543
Backlash free center distance, allowances (mm)	[jta]	-0.307	/ -0.457
Centre distance allowances (mm)	[Aa.e/i]	0.052	/ 0.000
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.042	/ 0.000
Radial clearance (mm)	[jr]	0.509	/ 0.307
Circumferential backlash (transverse section) (mm)	[jt]	0.413	/ 0.249
Torsional angle for fixed gear 1 (°)		0.3246	/0.1957
Normal backlash (mm)	[jn]	0.351	/ 0.212

7. GEAR ACCURACY

		----- GEAR 1 -----	GEAR 2 --
According to			
DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	9.00
Single pitch deviation (µm)	[fp]	10.00	9.00
Difference between adjacent pitches (µm)	[fu]	12.00	11.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	35.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	22.00
Concentricity deviation (µm)	[Fr]	28.00	25.00
Tooth Thickness Variation (µm)	[Rs]	16.00	15.00
Total radial composite deviation (µm)	[Fi"]	32.00	28.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	14.00	12.00
Total tangential composite deviation (µm)	[Fi']	42.00	38.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	15.00
Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)			
Maximum value for deviation error of axis (µm)	[fSigbet]	36.00	(Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00	

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	122.2	11.1
Mean coeff. of friction (acc. Niemann)	[mum]	0.032	
Wear sliding coef. by Niemann	[zetw]	0.687	
Power loss from gear load (kW)	[PVZ]	2.022	
(Meshing efficiency (%))	[etaz]	99.604	
Weight - calculated with da (kg)	[Mass]	314.097	33.402
Total weight (kg)	[Mass]	347.499	
Moment of inertia (System referenced to wheel 1):			

calculation without consideration of the exact tooth shape
 single gears ((da+df)/2...di) (kg*m²) [TraeghMom] 8.52585 0.07571
 System ((da+df)/2...di) (kg*m²) [TraeghMom] 9.35941

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
 Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
 Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
 The calculation is done for the Operating pitch circle..
- Details of calculation method:
 cg according to method B
 KV according to method B
 KHb, KFb according method C
 KHa, KFa according to method B

End report lines: 502

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----- File -----
Name : i21
Changed by : jirisuch on: 14.03.2014 at: 18:05:26

Important hint: At least one warning has occurred during the calculation:

1-> Notice to gear 1:
NOT POSSIBLE TO MEASURE BASE TANGENT LENGTH!
The width of the gear is too small, hence the tooth thickness too big,
so that the required length for the measurement exceed the face width.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 --
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	323.4	1073.0
Torque (Nm)	[T]	15067.9	4541.0
Application factor	[KA]		1.20
Required service life	[H]		20000.00
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 --
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	73	22
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 --
Surface hardness		HRC 56	HRC 56
Fatigue strength. tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C
Dedendum coefficient [hfP*] 1.250
Root radius factor [rhofP*] 0.250
Addendum coefficient [haP*] 1.000

Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofpP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in)	3.4	3.4
	[Ca]		

Lubrication type	oil injection lubrication	
Type of oil	Oil: ISO-VG 46	
Lubricant base	Mineral-oil base	
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	46.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	6.70
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.880
Oil temperature (°C)	[TS]	70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.301	
Gear ratio	[u]	3.318	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alf]	21.880	
Working transverse pressure angle (°)	[alfwt]	22.122	
	[alfwt.e/i]	22.146 / 22.122	
Working pressure angle at normal section (°)	[alfwn]	20.219	
Helix angle at operating pitch circle (°)	[betaw]	25.037	
Base helix angle (°)	[betab]	23.399	
Reference centre distance (mm)	[ad]	314.463	
Sum of profile shift coefficients	[Summexi]	0.0900	
Profile shift coefficient	[x]	-0.1753	0.2654
Tooth thickness (Arc) (module)	[sn*]	1.4432	1.7640
Tip alteration (mm)	[k*mn]	-0.003	-0.003
Reference diameter (mm)	[d]	483.280	145.646
Base diameter (mm)	[db]	448.466	135.154
Tip diameter (mm)	[da]	493.170	160.824
(mm)	[da.e/i]	493.170 / 492.920	160.824 / 160.814
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.250	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	493.170	160.824
(mm)	[dFa.e/i]	493.170 / 492.920	160.824 / 160.814
Active tip diameter (mm)	[dNa.e/i]	493.170 / 492.920	160.824 / 160.814
Operating pitch diameter (mm)	[dw]	484.105	145.895
(mm)	[dw.e/i]	484.185 / 484.105	145.919 / 145.895
Root diameter (mm)	[df]	466.176	133.830
Generating Profile shift coefficient	[xE.e/i]	-0.2051 / -0.2188	0.2436 / 0.2322
Manufactured root diameter with xE (mm)	[df.e/i]	465.818 / 465.654	133.569 / 133.432
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.876 / 1.631	1.818 / 1.679
Active root diameter (mm)	[dNf]	472.914	138.909
(mm)	[dNf.e/i]	473.007 / 472.914	139.115 / 138.909
Root form diameter (mm)	[dFf]	469.663	137.998
(mm)	[dFf.e/i]	469.379 / 469.249	137.858 / 137.786
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	1.879 / 1.767	0.665 / 0.526
Addendum (mm)	[ha = mn * (haP*+x)]	4.945	7.589
(mm)	[ha.e/i]	4.945 / 4.820	7.589 / 7.584

Dedendum (mm)	[hf = mn * (hfP*-x)]	8.552	5.908
(mm)	[hf.e/i]	8.731 / 8.813	6.038 / 6.107
Roll angle at dFa (°)	[xsi_dFa.e/i]	26.212 / 26.135	36.952 / 36.944
Roll angle to dNa (°)	[xsi_dNa.e/i]	26.212 / 26.135	36.952 / 36.944
Roll angle to dNf (°)	[xsi_dNf.e/i]	19.212 / 19.175	13.972 / 13.600
Roll angle at dFf (°)	[xsi_dFf.e/i]	17.700 / 17.644	11.517 / 11.361
Tooth height (mm)	[H]	13.497	13.497
Virtual gear no. of teeth	[zn]	95.628	28.820
Normal tooth thickness at tip cyl. (mm)	[san]	4.925	3.970
(mm)	[san.e/i]	4.894 / 4.732	3.873 / 3.813
Normal spacewidth at root cylinder (mm)	[efn]	4.601	0.000
(mm)	[efn.e/i]	4.632 / 4.647	0.000 / 0.000
Max. sliding velocity at tip (m/s)	[vga]	1.671	2.356
Specific sliding at the tip	[zetaa]	0.481	0.481
Specific sliding at the root	[zetaf]	-0.927	-0.927
Sliding factor on tip	[Kga]	0.204	0.287
Sliding factor on root	[Kgf]	-0.287	-0.204
Pitch on reference circle (mm)	[pt]		20.798
Base pitch (mm)	[pbt]		19.300
Transverse pitch on contact-path (mm)	[pet]		19.300
Lead height (mm)	[pz]	3255.935	981.241
Axial pitch (mm)	[px]		44.602
Length of path of contact (mm)	[ga, e/i]	27.542	(27.542 / 27.094)
Length T1-A, T2-A (mm)	[T1A, T2A]	75.042 (75.042/75.189)	43.582 (43.582/43.573)
Length T1-B (mm)	[T1B, T2B]	83.284 (83.284/82.983)	35.340 (35.340/35.779)
Length T1-C (mm)	[T1C, T2C]	91.153 (91.153/91.259)	27.471 (27.471/27.503)
Length T1-D (mm)	[T1D, T2D]	94.342 (94.342/94.489)	24.282 (24.282/24.273)
Length T1-E (mm)	[T1E, T2E]	102.584 (102.584/102.283)	16.040 (16.040/16.479)
Length T1-T2 (mm)	[T1T2]	118.624	(118.624 / 118.762)
Diameter of single contact point B (mm)	[d-B]	478.401 (478.401/478.191)	152.520 (152.520/152.929)
Diameter of single contact point D (mm)	[d-D]	486.543 (486.543/486.657)	143.615 (143.615/143.609)
Addendum contact ratio	[eps]	0.592 (0.592/ 0.571)	0.835 (0.835/ 0.833)
Minimal length of contact line (mm)	[Lmin]		97.027
Transverse contact ratio	[eps_a]		1.427
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.427	/ 1.415 / 1.404
Overlap ratio	[eps_b-beH (eps_b-b)]		1.569 (3.139)
Total contact ratio	[eps_g]		2.997 (4.566)
Total contact ratio with allowances	[eps_g.e/m/i]	2.997/2.985/2.973	(4.566/4.554/4.543)

2. FACTORS OF GENERAL INFLUENCE

	----- GEAR 1 -----	GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	62356.7
Axial force (N)	[Fa]	0.0
Radial force (N)	[Fr]	25042.3
Normal force (N)	[Fnorm]	73218.7
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	445.41
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	62250.4
Axial force (N)	[Faw]	0.0
Radial force (N)	[Frw]	25305.5
Circumferential speed pitch d.. (m/sec)	[v]	8.18
Running-in value (µm)	[yp]	0.8
Running-in value (µm)	[yf]	0.8
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	13.146
Meshing stiffness (N/mm/µm)	[cg]	17.356
Reduced mass (kg/mm)	[mRed]	0.07223
Resonance speed (min-1)	[nE1]	2028
Nominal speed (-)	[N]	0.159
Subcritical range		
Running-in value (µm)	[ya]	0.8
Bearing distance l of pinion shaft (mm)	[l]	336.000
Distance s of pinion shaft (mm)	[s]	16.800
Outside diameter of pinion shaft (mm)	[dsh]	132.400
Load according to figure 6.8, DIN 3990-1:1987 [-]		4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)		
Coefficient K' according figure 6.8, DIN 3990-1:1987 [K']		-1.00
Without support effect		
Tooth trace deviation (active) (µm)	[Fby]	4.25

from deformation of shaft (μm)	[fsh*B1]		6.49
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (μm)	[fma*B2]		10.00
Tooth trace deviation, theoretical (μm)	[Fbx]		5.00
Running-in value (μm)	[yb]		0.8
Dynamic factor	[KV]		1.030
Face load factor - flank	[KHb]		1.067
- Tooth root	[KFb]		1.054
- Scuffing	[KBb]		1.067
Transverse load factor - flank	[KH α]		1.026
- Tooth root	[KF α]		1.026
- Scuffing	[KB α]		1.026
Helical load factor scuffing	[Kbg]		1.283
Number of load cycles (in mio.)	[NL]	388.044	1287.600

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	GEAR 2 --
Tooth form factor	[YF]	1.33	1.18
Stress correction factor	[YS]	2.25	2.42
Working angle ($^{\circ}$)	[alfFen]	19.42	20.38
Bending lever arm (mm)	[hF]	6.68	5.56
Tooth thickness at root (mm)	[sFn]	13.47	13.00
Tooth root radius (mm)	[roF]	2.43	2.29
(hF* = 1.113/0.927 sFn* = 2.245/2.166 roF* = 0.405/0.381 dsFn = 468.04/135.57 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm ²)			
Tooth root stress (N/mm ²)	[sigF0] [sigF]	176.26 235.63	168.11 224.73
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.002	1.003
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.950	0.950
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm ²)	[sigFG]	702.64	703.09
Permissible tooth root stress (N/mm ²)	[sigFP=sigFG/SFmin]	501.89	502.20
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	2.98	3.13
Transmittable power (kW)	[kWRating]	1086.83	1140.27

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	GEAR 2 --
Zone factor	[ZH]		2.290
Elasticity coefficient (N ^{.5} /mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.837	
Helix angle factor	[Zbet]	0.952	
Effective facewidth (mm)	[beff]	70.00	
Nominal flank pressure (N/mm ²)	[sigH0]	691.00	
Surface pressure at operating pitch circle (N/mm ²)			
Single tooth contact factor	[sigHw]	803.85	
Flank pressure (N/mm ²)	[ZB, ZD] [sigH]	1.00 803.85	1.00 803.85
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	0.995	0.995
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	0.920	0.920
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm ²)	[sigHG]	1122.01	1122.01

Permissible surface pressure (N/mm ²) [sigHP=sigHG/SHmin]	1122.01	1122.01
Safety for surface pressure at operating pitch circle		
Required safety [SHw]	1.40	1.40
[SHmin]	1.00	1.00
Transmittable power (kW) [kWRating]	994.09	994.09
Safety for stress at single tooth contact		
(Safety regarding nominal torque) [SHBD=sigHG/sigH]	1.40	1.40
[(SHBD)^2]	1.95	1.95

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)			
[XWrelT]	1.000		
Thermal contact factor (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	3.40	3.40
Optimal tip relief (µm)	[Ceff]	20.53	
Effective facewidth (mm)	[beff]	70.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	773.101	
Pressure angle factor (eps1: 0.592, eps2: 0.835)	[Xalfbet]	0.990	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	108.49	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	68.24	
Scuffing temperature (°C)	[theS]	469.40	
Coordinate gamma (point of highest temp.)	[Gamma]	0.286	
[Gamma.A]= -0.177 [Gamma.E]= 0.125			
Highest contact temp. (°C)	[theB]	176.73	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Geometry factor	[XB]	0.135	
Load sharing factor	[XGam]	1.000	
Dynamic viscosity (mPa*s)	[etaM]	4.70	
Coefficient of friction	[mym]	0.103	
Required safety	[SBmin]	2.000	
Safety factor for scuffing (flash-temp)	[SB]	3.742	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	94.30	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	28.93	
Integral scuffing temperature (°C)	[theSint]	469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.270	
Dynamic viscosity (mPa*s)	[etaOil]	12.31	
Averaged coefficient of friction	[mym]	0.086	
Geometry factor	[XBE]	0.259	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.026	
Integral tooth flank temperature (°C)	[theint]	137.70	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	3.409	
Safety referring to transferred torque	[SSL]	5.899	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 --
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.095 / -0.145
Number of teeth spanned	[k]	11.000	4.000
Base tangent length (no backlash) (mm)	[Wk]	193.379	65.529
Actual base tangent length ('span') (mm)	[Wk.e/i]	193.257 / 193.200	65.440 / 65.393
Diameter of contact point (mm)	[dMwk.m]	482.256	147.889
> Base tangent length Gear 1 is not measurable (Gear too thin)			
Theoretical diameter of ball/pin (mm)	[DM]	10.027	10.702
Eff. Diameter of ball/pin (mm)	[DMeff]	10.500	11.000

Theor. dim. centre to ball (mm)	[MrK]	248.218	82.429
Actual dimension centre to ball (mm)	[MrK.e/i]	248.045 / 247.965	82.327 / 82.274
Diameter of contact point (mm)	[dMMr.m]	481.900	149.069
Diametral measurement over two balls without clearance (mm)	[MdK]	496.324	164.859
Actual dimension over balls (mm)	[MdK.e/i]	495.978 / 495.817	164.655 / 164.547
Diametral measurement over rolls without clearance (mm)	[MdR]	496.437	164.859
Actual dimension over rolls (mm)	[MdR.e/i]	496.090 / 495.930	164.655 / 164.547
Dimensions over 3 rolls without clearance (mm)	[Md3R]	496.437	0.000
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	496.090 / 495.930	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)			
	['sn]	8.659	10.577
Actual chordal tooth thickness (mm)	['sn.e/i]	8.529 / 8.469	10.482 / 10.432
Reference chordal height from da.m (mm)	[ha]	4.914	7.745
Tooth thickness (Arc) (mm)	[sn]	8.659	10.584
	(mm) [sn.e/i]	8.529 / 8.469	10.489 / 10.439
Backlash free center distance (mm) [aControl.e/i] 314.693 / 314.543			
Backlash free center distance, allowances (mm)			
	[jta]	-0.307 / -0.457	
Centre distance allowances (mm)	[Aa.e/i]	0.052 / 0.000	
Circumferential backlash from Aa (mm)	[jt Aa.e/i]	0.042 / 0.000	
Radial clearance (mm)	[j _r]	0.509 / 0.307	
Circumferential backlash (transverse section) (mm)	[jt]	0.413 / 0.249	
Torsional angle for fixed gear 1 (°)		0.3246 / 0.1957	
Normal backlash (mm)	[jn]	0.351 / 0.212	

7. GEAR ACCURACY

----- GEAR 1 ----- GEAR 2 --

According to

DIN 3961:1978:

Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	9.00
Single pitch deviation (µm)	[fp]	10.00	9.00
Difference between adjacent pitches (µm)	[fu]	12.00	11.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	35.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	22.00
Concentricity deviation (µm)	[Fr]	28.00	25.00
Tooth Thickness Variation (µm)	[Rs]	16.00	15.00
Total radial composite deviation (µm)	[Fi'']	32.00	28.00
Radial tooth-to-tooth composite deviation (µm)	[fi'']	14.00	12.00
Total tangential composite deviation (µm)	[Fi']	42.00	38.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	15.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)

Maximum value for deviation error of axis (µm)	[fSigbet]	36.00 (Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	122.2	11.1
Mean coeff. of friction (acc. Niemann)	[mum]	0.051	
Wear sliding coef. by Niemann	[zetw]	0.687	
Power loss from gear load (kW)	[PVZ]	3.243	
(Meshing efficiency (%))	[etaz]	99.364	
Weight - calculated with da (kg)	[Mass]	314.097	33.402
Total weight (kg)	[Mass]	347.499	
Moment of inertia (System referenced to wheel 1): calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m ²)	[TraeghMom]	8.52585	0.07571
System ((da+df)/2...di) (kg*m ²)	[TraeghMom]	9.35941	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
The calculation is done for the Operating pitch circle..
- Details of calculation method:
 - cg according to method B
 - KV according to method B
 - KHb, KFb according method C
 - KHa, KFa according to method B

End report

lines: 502

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----- File -----
Name : i34
Changed by : jirisuch on: 14.03.2014 at: 18:05:57

Important hint: At least one warning has occurred during the calculation:

1-> The circumferential speed is very high (24.9200 m/s)!
You have to take adequate action to
guarantee proper lubrication.

2-> Notice to gear 1:
NOT POSSIBLE TO MEASURE BASE TANGENT LENGTH!
The width of the gear is too small, hence the tooth thickness too big,
so that the required length for the measurement exceed the face width.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 --
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	1073.0	2567.5
Torque (Nm)	[T]	4541.0	1897.7
Application factor	[KA]		1.20
Required service life	[H]		20000.00
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 --
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	67	28
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 --
Surface hardness		HRC 56	HRC 56
Fatigue strength. tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofpP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in)		
	[Ca]	3.4	3.4

Lubrication type

oil injection lubrication

Type of oil

Oil: ISO-VG 46

Lubricant base

Mineral-oil base

Kinem. viscosity oil at 40 °C (mm²/s)

[nu40] 46.00

Kinem. viscosity oil at 100 °C (mm²/s)

[nu100] 6.70

FZG test A/8.3/90 (

ISO 14635-1:2006)

[FZGtestA] 12

Specific density at 15 °C (kg/dm³)

[roOil] 0.880

Oil temperature (°C)

[TS] 70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.418	
Gear ratio	[u]	2.393	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	22.122	
	[alfwt.e/i]	22.146 / 22.122	
Working pressure angle at normal section (°)	[alfwn]	20.219	
Helix angle at operating pitch circle (°)	[betaw]	25.037	
Base helix angle (°)	[betab]	23.399	
Reference centre distance (mm)	[ad]	314.463	
Sum of profile shift coefficients	[Summexi]	0.0900	
Profile shift coefficient	[x]	-0.1041	0.1941
Tooth thickness (Arc) (module)	[sn*]	1.4950	1.7121
Tip alteration (mm)	[k*mn]	-0.003	-0.003
Reference diameter (mm)	[d]	443.558	185.367
Base diameter (mm)	[db]	411.606	172.015
Tip diameter (mm)	[da]	454.303	199.691
(mm)	[da.e/i]	454.303 / 454.053	199.691 / 199.681
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.250	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	454.303	199.691
(mm)	[dFa.e/i]	454.303 / 454.053	199.691 / 199.681
Active tip diameter (mm)	[dNa.e/i]	454.303 / 454.053	199.691 / 199.681
Operating pitch diameter (mm)	[dw]	444.316	185.684
(mm)	[dw.e/i]	444.389 / 444.316	185.715 / 185.684
Root diameter (mm)	[df]	427.309	172.697
Generating Profile shift coefficient	[xE.e/i]	-0.1338 / -0.1476	0.1724 / 0.1609
Manufactured root diameter with xE (mm)	[df.e/i]	426.952 / 426.787	172.436 / 172.298
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.876 / 1.631	1.818 / 1.679
Active root diameter (mm)	[dNf]	433.437	177.795
(mm)	[dNf.e/i]	433.529 / 433.437	178.017 / 177.795
Root form diameter (mm)	[dFf]	430.752	176.690

	(mm)	[dFf.e/i]	430.470 / 430.341	176.531 / 176.449
Reserve (dNf-dFf)/2 (mm)		[cF.e/i]	1.594 / 1.483	0.784 / 0.632
Addendum (mm)	[ha = mn * (haP**x)]		5.373	7.162
(mm)		[ha.e/i]	5.373 / 5.248	7.162 / 7.157
Dedendum (mm)	[hf = mn * (hfP**x)]		8.124	6.335
(mm)		[hf.e/i]	8.303 / 8.386	6.466 / 6.535
Roll angle at dFa (°)		[xsi_dFa.e/i]	26.765 / 26.683	33.784 / 33.777
Roll angle to dNa (°)		[xsi_dNa.e/i]	26.765 / 26.683	33.784 / 33.777
Roll angle to dNf (°)		[xsi_dNf.e/i]	18.948 / 18.906	15.267 / 14.979
Roll angle at dFf (°)		[xsi_dFf.e/i]	17.544 / 17.483	13.216 / 13.093
Tooth height (mm)		[H]	13.497	13.497
Virtual gear no. of teeth		[zn]	87.769	36.679
Normal tooth thickness at tip cyl. (mm)		[san]	4.880	4.280
(mm)		[san.e/i]	4.850 / 4.686	4.185 / 4.126
Normal spacewidth at root cylinder (mm)		[efn]	4.587	5.001
(mm)		[efn.e/i]	4.620 / 4.635	5.065 / 5.101
Max. sliding velocity at tip (m/s)		[vga]	4.757	6.005
Specific sliding at the tip		[zetaa]	0.440	0.440
Specific sliding at the root		[zetaf]	-0.787	-0.787
Sliding factor on tip		[Kga]	0.191	0.241
Sliding factor on root		[Kgf]	-0.241	-0.191
Pitch on reference circle (mm)		[pt]		20.798
Base pitch (mm)		[pbt]		19.300
Transverse pitch on contact-path (mm)		[pet]		19.300
Lead height (mm)		[pz]	2988.324	1248.852
Axial pitch (mm)		[px]		44.602
Length of path of contact (mm)		[ga, e/i]	28.229 (28.229 / 27.785)	
Length T1-A, T2-A (mm)		[T1A, T2A]	67.911(67.911/68.059)	50.713(50.713/50.704)
Length T1-B (mm)		[T1B, T2B]	76.840(76.840/76.544)	41.784(41.784/42.218)
Length T1-C (mm)		[T1C, T2C]	83.661(83.661/83.759)	34.963(34.963/35.004)
Length T1-D (mm)		[T1D, T2D]	87.211(87.211/87.359)	31.413(31.413/31.404)
Length T1-E (mm)		[T1E, T2E]	96.140(96.140/95.844)	22.484(22.484/22.918)
Length T1-T2 (mm)		[T1T2]	118.624 (118.624 / 118.762)	
Diameter of single contact point B (mm)		[d-B]	439.360(439.360/439.153)	191.240(191.240/191.621)
Diameter of single contact point D (mm)		[d-D]	447.038(447.038/447.153)	183.129(183.129/183.122)
Addendum contact ratio		[eps]	0.647(0.647/ 0.626)	0.816(0.816/ 0.813)
Minimal length of contact line (mm)		[Lmin]		100.316
Transverse contact ratio		[eps_a]		1.463
Transverse contact ratio with allowances		[eps_a.e/m/i]	1.463 / 1.451 / 1.440	
Overlap ratio		[eps_b-beH (eps_b-b)]		1.569 (3.139)
Total contact ratio		[eps_g]		3.032 (4.602)
Total contact ratio with allowances		[eps_g.e/m/i]	3.032/3.021/3.009	(4.602/4.590/4.579)

2. FACTORS OF GENERAL INFLUENCE

		----- GEAR 1 -----	GEAR 2 --
Nominal circum. force at pitch circle (N)			
	[Ft]	20475.3	
Axial force (N)	[Fa]	0.0	
Radial force (N)	[Fr]	8222.8	
Normal force (N)	[Fnorm]	24041.9	
Tangent.load at p.c.d.per mm (N/mm) (N/mm)			
	[w]	146.25	
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]	20440.4	
Axial force (N)	[Faw]	0.0	
Radial force (N)	[Frw]	8309.3	
Circumferential speed pitch d.. (m/sec)	[v]	24.92	
Running-in value (µm)	[yp]	0.8	
Running-in value (µm)	[yf]	0.8	
Correction coefficient	[CM]	0.800	
Gear body coefficient	[CR]	1.000	
Reference profile coefficient	[CBS]	0.975	
Material coefficient	[E/Est]	1.000	
Singular tooth stiffness (N/mm/µm)	[c']	13.272	
Meshing stiffness (N/mm/µm)	[cg]	17.877	
Reduced mass (kg/mm)	[mRed]	0.10564	
Resonance speed (min-1)	[nE1]	1854	
Nominal speed (-)	[N]	0.579	
Subcritical range			
Running-in value (µm)	[ya]	0.8	
Bearing distance l of pinion shaft (mm)	[l]	336.000	
Distance s of pinion shaft (mm)	[s]	16.800	
Outside diameter of pinion shaft (mm)	[dsh]	168.000	
Load according to figure 6.8, DIN 3990-1:1987 [-]			4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)			

Coefficient K' according figure 6.8, DIN 3990-1:1987 [K']		-1.00	
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]	4.36	
from deformation of shaft (µm)	[fsh*B1]	1.81	
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (µm)	[fma*B2]	10.00	
Tooth trace deviation, theoretical (µm)	[Fbx]	5.13	
Running-in value (µm)	[yb]	0.8	
Dynamic factor	[KV]	1.252	
Face load factor - flank	[KHb]	1.177	
- Tooth root	[KFb]	1.142	
- Scuffing	[KBb]	1.177	
Transverse load factor - flank	[KHα]	1.196	
- Tooth root	[KFα]	1.196	
- Scuffing	[KBα]	1.196	
Helical load factor scuffing	[Kbg]	1.285	
Number of load cycles (in mio.)	[NL]	1287.600	3081.043

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	GEAR 2 --
Tooth form factor	[YF]	1.26	1.17
Stress correction factor	[YS]	2.33	2.42
Working angle (°)	[alfFen]	19.40	19.81
Bending lever arm (mm)	[hF]	6.33	5.56
Tooth thickness at root (mm)	[sFn]	13.48	13.12
Tooth root radius (mm)	[roF]	2.38	2.33
(hF* = 1.055/0.927 sFn* = 2.247/2.186 roF* = 0.397/0.389 dsFn = 429.15/174.48 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm²)	[sigF0]	56.46	54.37
Tooth root stress (N/mm²)	[sigF]	115.80	111.51
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.003	1.003
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.950	0.950
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm²)	[sigFG]	703.03	702.92
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	502.16	502.09
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	6.07	6.30
Transmittable power (kW)	[kWRating]	2212.63	2297.50

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	GEAR 2 --
Zone factor	[ZH]		2.290
Elasticity coefficient (N ^{.5} /mm)	[ZE]		189.812
Contact ratio factor	[Zeps]		0.827
Helix angle factor	[Zbet]		0.952
Effective facewidth (mm)	[beff]		70.00
Nominal flank pressure (N/mm²)	[sigH0]		361.88
Surface pressure at operating pitch circle (N/mm²)	[sigHw]		526.34
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	526.34	526.34
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	1.027	1.027
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000

	[ZL*ZV*ZR*ZNT]	0.950	0.950
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm ²)	[sigHG]	1158.66	1158.66
Permissible surface pressure (N/mm ²) [sigHP=sigHG/SHmin]		1158.66	1158.66
Safety for surface pressure at operating pitch circle			
	[SHw]	2.20	2.20
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	2472.67	2472.67
Safety for stress at single tooth contact			
	[SHBD=sigHG/sigH]	2.20	2.20
(Safety regarding nominal torque)	[(SHBD)^2]	4.85	4.85

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)			
	[XWrelT]	1.000	
Thermal contact factor (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	3.40	3.40
Optimal tip relief (µm)	[Ceff]	6.54	
Effective facewidth (mm)	[beff]	70.000	
Applicable circumferential force/facewidth (N/mm)			
	[wBt]	397.572	
Pressure angle factor (eps1: 0.647, eps2: 0.816)	[Xalfbet]	0.990	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	86.90	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	29.96	
Scuffing temperature (°C)	[theS]	469.40	
Coordinate gamma (point of highest temp.)	[Gamma]	0.195	
[Gamma.A]= -0.188 [Gamma.E]= 0.149			
Highest contact temp. (°C)	[theB]	116.86	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} *mm)	[XM]	50.058	
Geometry factor	[XB]	0.100	
Load sharing factor	[XGam]	1.000	
Dynamic viscosity (mPa*s)	[etaM]	7.69	
Coefficient of friction	[mym]	0.058	
Required safety	[SBmin]	2.000	
Safety factor for scuffing (flash-temp)	[SB]	8.521	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	83.46	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	16.02	
Integral scuffing temperature (°C)	[theSint]	469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} *mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.268	
Dynamic viscosity (mPa*s)	[etaOil]	12.31	
Averaged coefficient of friction	[mym]	0.053	
Geometry factor	[XBE]	0.220	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.023	
Integral tooth flank temperature (°C)	[theint]	107.49	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	4.367	
Safety referring to transferred torque	[SSL]	10.653	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 -----
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.095 / -0.145
Number of teeth spanned	[k]	10.000	5.000
Base tangent length (no backlash) (mm)	[Wk]	175.292	83.617
Actual base tangent length ('span') (mm)	[Wk.e/i]	175.169 / 175.113	83.527 / 83.480
Diameter of contact point (mm)	[dMWk.m]	441.878	188.314

> Base tangent length Gear 1 is not measurable (Gear too thin)

Theoretical diameter of ball/pin (mm)	[DM]	10.051	10.438
Eff. Diameter of ball/pin (mm)	[DMeff]	10.500	10.500
Theor. dim. centre to ball (mm)	[MrK]	228.766	101.181
Actual dimension centre to ball (mm)	[MrK.e/i]	228.595 / 228.516	101.071 / 101.013
Diameter of contact point (mm)	[dMMr.m]	442.960	187.541
Diametral measurement over two balls without clearance (mm)	[MdK]	457.409	202.362
Actual dimension over balls (mm)	[MdK.e/i]	457.067 / 456.909	202.142 / 202.026
Diametral measurement over rolls without clearance (mm)	[MdR]	457.532	202.362
Actual dimension over rolls (mm)	[MdR.e/i]	457.190 / 457.032	202.142 / 202.026
Dimensions over 3 rolls without clearance (mm)	[Md3R]	457.532	0.000
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	457.190 / 457.032	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)	['sn]	8.970	10.269
Actual chordal tooth thickness (mm)	['sn.e/i]	8.840 / 8.780	10.174 / 10.124
Reference chordal height from da.m (mm)	[ha]	5.347	7.276
Tooth thickness (Arc) (mm)	[sn]	8.970	10.273
(mm)	[sn.e/i]	8.840 / 8.780	10.178 / 10.128
Backlash free center distance (mm)	[aControl.e/i]	314.693	/314.543
Backlash free center distance, allowances (mm)	[jta]	-0.307	/ -0.457
Centre distance allowances (mm)	[Aa.e/i]	0.052	/ 0.000
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.042	/ 0.000
Radial clearance (mm)	[jr]	0.509	/ 0.307
Circumferential backlash (transverse section) (mm)	[jt]	0.413	/ 0.249
Torsional angle for fixed gear 1 (°)		0.2550	/0.1537
Normal backlash (mm)	[jn]	0.351	/ 0.212

7. GEAR ACCURACY

		----- GEAR 1 -----	----- GEAR 2 -----
According to			
DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	9.00
Single pitch deviation (µm)	[fp]	10.00	9.00
Difference between adjacent pitches (µm)	[fu]	12.00	11.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	35.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	22.00
Concentricity deviation (µm)	[Fr]	28.00	25.00
Tooth Thickness Variation (µm)	[Rs]	16.00	15.00
Total radial composite deviation (µm)	[Fi"]	32.00	28.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	14.00	12.00
Total tangential composite deviation (µm)	[Fi']	42.00	38.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	15.00
Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)			
Maximum value for deviation error of axis (µm)	[fSigbet]	36.00	(Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00	

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	106.0	18.5
Mean coeff. of friction (acc. Niemann)	[mum]	0.030	
Wear sliding coef. by Niemann	[zetw]	0.644	
Power loss from gear load (kW)	[PVZ]	1.625	
(Meshing efficiency (%))	[etaz]	99.682	
Weight - calculated with da (kg)	[Mass]	266.540	51.498
Total weight (kg)	[Mass]	318.037	
Moment of inertia (System referenced to wheel 1):			

calculation without consideration of the exact tooth shape
 single gears ((da+df)/2...di) (kg*m²) [TraeghMom] 6.07936 0.19332
 System ((da+df)/2...di) (kg*m²) [TraeghMom] 7.18627

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
 Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
- Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
- The calculation is done for the Operating pitch circle..
- Details of calculation method:
 cg according to method B
 KV according to method B
 KHb, KFb according method C
 KHa, KFa according to method B

End report lines: 502

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----- File -----
Name : i43
Changed by : jirisuch on: 14.03.2014 at: 18:06:37

Important hint: At least one warning has occurred during the calculation:

1-> Notice to gear 1:
NOT POSSIBLE TO MEASURE BASE TANGENT LENGTH!
The width of the gear is too small, hence the tooth thickness too big,
so that the required length for the measurement exceed the face width.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 --
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	448.4	1073.0
Torque (Nm)	[T]	10866.0	4541.0
Application factor	[KA]		1.20
Required service life	[H]		20000.00
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 --
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	67	28
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 --
Surface hardness		HRC 56	HRC 56
Fatigue strength. tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C
Dedendum coefficient [hfP*] 1.250
Root radius factor [rhofP*] 0.250
Addendum coefficient [haP*] 1.000

Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofpP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in)		
	[Ca]	3.4	3.4

Lubrication type	oil injection lubrication	
Type of oil	Oil: ISO-VG 46	
Lubricant base	Mineral-oil base	
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	46.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	6.70
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.880
Oil temperature (°C)	[TS]	70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.418	
Gear ratio	[u]	2.393	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	22.122	
Working pressure angle at normal section (°) [alfwn]	[alfwt.e/i]	22.146 / 22.122	
Helix angle at operating pitch circle (°)	[betaw]	20.219	
Base helix angle (°)	[betab]	25.037	
Reference centre distance (mm)	[ad]	23.399	
Sum of profile shift coefficients	[Summexi]	314.463	
Profile shift coefficient	[x]	0.0900	
Tooth thickness (Arc) (module)	[sn*]	-0.1041	0.1941
		1.4950	1.7121
Tip alteration (mm)	[k*mn]	-0.003	-0.003
Reference diameter (mm)	[d]	443.558	185.367
Base diameter (mm)	[db]	411.606	172.015
Tip diameter (mm)	[da]	454.303	199.691
(mm)	[da.e/i]	454.303 / 454.053	199.691 / 199.681
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.250	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	454.303	199.691
(mm)	[dFa.e/i]	454.303 / 454.053	199.691 / 199.681
Active tip diameter (mm)	[dNa.e/i]	454.303 / 454.053	199.691 / 199.681
Operating pitch diameter (mm)	[dw]	444.316	185.684
(mm)	[dw.e/i]	444.389 / 444.316	185.715 / 185.684
Root diameter (mm)	[df]	427.309	172.697
Generating Profile shift coefficient	[xE.e/i]	-0.1338 / -0.1476	0.1724 / 0.1609
Manufactured root diameter with xE (mm)	[df.e/i]	426.952 / 426.787	172.436 / 172.298
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.876 / 1.631	1.818 / 1.679
Active root diameter (mm)	[dNf]	433.437	177.795
(mm)	[dNf.e/i]	433.529 / 433.437	178.017 / 177.795
Root form diameter (mm)	[dFf]	430.752	176.690
(mm)	[dFf.e/i]	430.470 / 430.341	176.531 / 176.449
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	1.594 / 1.483	0.784 / 0.632
Addendum (mm)	[ha = mn * (haP**x)]	5.373	7.162
(mm)	[ha.e/i]	5.373 / 5.248	7.162 / 7.157

Dedendum (mm)	[hf = mn * (hfP*-x)]	8.124	6.335
(mm)	[hf.e/i]	8.303 / 8.386	6.466 / 6.535
Roll angle at dFa (°)	[xsi_dFa.e/i]	26.765 / 26.683	33.784 / 33.777
Roll angle to dNa (°)	[xsi_dNa.e/i]	26.765 / 26.683	33.784 / 33.777
Roll angle to dNf (°)	[xsi_dNf.e/i]	18.948 / 18.906	15.267 / 14.979
Roll angle at dFf (°)	[xsi_dFf.e/i]	17.544 / 17.483	13.216 / 13.093
Tooth height (mm)	[H]	13.497	13.497
Virtual gear no. of teeth	[zn]	87.769	36.679
Normal tooth thickness at tip cyl. (mm)	[san]	4.880	4.280
(mm)	[san.e/i]	4.850 / 4.686	4.185 / 4.126
Normal spacewidth at root cylinder (mm)	[efn]	4.587	5.001
(mm)	[efn.e/i]	4.620 / 4.635	5.065 / 5.101
Max. sliding velocity at tip (m/s)	[vga]	1.988	2.509
Specific sliding at the tip	[zetaa]	0.440	0.440
Specific sliding at the root	[zetaf]	-0.787	-0.787
Sliding factor on tip	[Kga]	0.191	0.241
Sliding factor on root	[Kgf]	-0.241	-0.191
Pitch on reference circle (mm)	[pt]		20.798
Base pitch (mm)	[pbt]		19.300
Transverse pitch on contact-path (mm)	[pet]		19.300
Lead height (mm)	[pz]	2988.324	1248.852
Axial pitch (mm)	[px]		44.602
Length of path of contact (mm)	[ga, e/i]	28.229	(28.229 / 27.785)
Length T1-A, T2-A (mm)	[T1A, T2A]	67.911(67.911/68.059)	50.713(50.713/50.704)
Length T1-B (mm)	[T1B, T2B]	76.840(76.840/76.544)	41.784(41.784/42.218)
Length T1-C (mm)	[T1C, T2C]	83.661(83.661/83.759)	34.963(34.963/35.004)
Length T1-D (mm)	[T1D, T2D]	87.211(87.211/87.359)	31.413(31.413/31.404)
Length T1-E (mm)	[T1E, T2E]	96.140(96.140/95.844)	22.484(22.484/22.918)
Length T1-T2 (mm)	[T1T2]	118.624	(118.624 / 118.762)
Diameter of single contact point B (mm)	[d-B]	439.360(439.360/439.153)	191.240(191.240/191.621)
Diameter of single contact point D (mm)	[d-D]	447.038(447.038/447.153)	183.129(183.129/183.122)
Addendum contact ratio	[eps]	0.647(0.647/ 0.626)	0.816(0.816/ 0.813)
Minimal length of contact line (mm)	[Lmin]		100.316
Transverse contact ratio	[eps_a]		1.463
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.463	/ 1.451 / 1.440
Overlap ratio	[eps_b-beH (eps_b-b)]		1.569 (3.139)
Total contact ratio	[eps_g]		3.032 (4.602)
Total contact ratio with allowances	[eps_g.e/m/i]	3.032/3.021/3.009	(4.602/4.590/4.579)

2. FACTORS OF GENERAL INFLUENCE

	----- GEAR 1 -----	GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	48994.6
Axial force (N)	[Fa]	0.0
Radial force (N)	[Fr]	19676.1
Normal force (N)	[Fnorm]	57528.9
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	349.96
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	48911.0
Axial force (N)	[Faw]	0.0
Radial force (N)	[Frw]	19882.9
Circumferential speed pitch d.. (m/sec)	[v]	10.41
Running-in value (µm)	[yp]	0.8
Running-in value (µm)	[yf]	0.8
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	13.272
Meshing stiffness (N/mm/µm)	[cg]	17.877
Reduced mass (kg/mm)	[mRed]	0.10564
Resonance speed (min-1)	[nE1]	1854
Nominal speed (-)	[N]	0.242
Subcritical range		
Running-in value (µm)	[ya]	0.8
Bearing distance l of pinion shaft (mm)	[l]	336.000
Distance s of pinion shaft (mm)	[s]	16.800
Outside diameter of pinion shaft (mm)	[dsh]	168.000
Load according to figure 6.8, DIN 3990-1:1987 [-]		4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)		
Coefficient K' according figure 6.8, DIN 3990-1:1987 [K']		-1.00
Without support effect		
Tooth trace deviation (active) (µm)	[Fby]	4.25

from deformation of shaft (μm)	[fsh*B1]		3.65
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (μm)	[fma*B2]		10.00
Tooth trace deviation, theoretical (μm)	[Fbx]		5.00
Running-in value (μm)	[yb]		0.8
Dynamic factor	[KV]		1.053
Face load factor - flank	[KHb]		1.086
- Tooth root	[KFb]		1.069
- Scuffing	[KBb]		1.086
Transverse load factor - flank	[KH α]		1.059
- Tooth root	[KF α]		1.059
- Scuffing	[KB α]		1.059
Helical load factor scuffing	[K β g]		1.285
Number of load cycles (in mio.)	[NL]	538.101	1287.600

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	GEAR 2 --
Tooth form factor	[YF]	1.26	1.17
Stress correction factor	[YS]	2.33	2.42
Working angle ($^{\circ}$)	[alfFen]	19.40	19.81
Bending lever arm (mm)	[hF]	6.33	5.56
Tooth thickness at root (mm)	[sFn]	13.48	13.12
Tooth root radius (mm)	[roF]	2.38	2.33
(hF* = 1.055/0.927 sFn* = 2.247/2.186 roF* = 0.397/0.389 dsFn = 429.15/174.48 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm 2)			
Tooth root stress (N/mm 2)	[sigF0] [sigF]	135.10 193.38	130.09 186.21
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.003	1.003
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.950	0.950
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm 2)	[sigFG]	703.03	702.92
Permissible tooth root stress (N/mm 2)	[sigFP=sigFG/SFmin]	502.16	502.09
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	3.64	3.77
Transmittable power (kW)	[kWRating]	1324.96	1375.78

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	GEAR 2 --
Zone factor	[ZH]		2.290
Elasticity coefficient (N $^{.5}$ /mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.827	
Helix angle factor	[Zbet]	0.952	
Effective facewidth (mm)	[beff]	70.00	
Nominal flank pressure (N/mm 2)	[sigH0]	559.78	
Surface pressure at operating pitch circle (N/mm 2)			
Single tooth contact factor	[sigHw]	674.98	
Flank pressure (N/mm 2)	[ZB, ZD] [sigH]	1.00 674.98	1.00 674.98
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	1.001	1.001
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	0.926	0.926
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm 2)	[sigHG]	1129.50	1129.50

Permissible surface pressure (N/mm ²) [sigHP=sigHG/SHmin]	1129.50	1129.50
Safety for surface pressure at operating pitch circle		
Required safety [SHw]	1.67	1.67
Transmittable power (kW) [SHmin]	1.00	1.00
Safety for stress at single tooth contact [kWRating]	1428.81	1428.81
(Safety regarding nominal torque) [SHBD=sigHG/sigH]	1.67	1.67
	[(SHBD)^2]	2.80

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type) [XS]		1.200	
Relative structure coefficient (Scuffing) [XWrelT]		1.000	
Thermal contact factor (N/mm/s ^{0.5} /K) [BM]	13.780		13.780
Relevant tip relief (µm) [Ca]	3.40		3.40
Optimal tip relief (µm) [Ceff]		15.66	
Effective facewidth (mm) [beff]		70.000	
Applicable circumferential force/facewidth (N/mm) [wBt]		653.839	
Pressure angle factor (eps1: 0.647, eps2: 0.816) [Xalfbet]		0.990	
Flash temperature-criteria			
Tooth mass temperature (°C) [theM-B]		93.25	
theM-B = theoil + XS*0.47*theflamax [theflamax]		41.23	
Scuffing temperature (°C) [theS]		469.40	
Coordinate gamma (point of highest temp.) [Gamma]		0.195	
[Gamma.A]= -0.188 [Gamma.E]= 0.149			
Highest contact temp. (°C) [theB]		134.49	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm) [XM]		50.058	
Geometry factor [XB]		0.100	
Load sharing factor [XGam]		1.000	
Dynamic viscosity (mPa*s) [etaM]		6.56	
Coefficient of friction [mym]		0.084	
Required safety [SBmin]		2.000	
Safety factor for scuffing (flash-temp) [SB]		6.193	
Integral temperature-criteria			
Tooth mass temperature (°C) [theM-C]		87.80	
theM-C = theoil + XS*0.70*theflaint [theflaint]		21.19	
Integral scuffing temperature (°C) [theSint]		469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm) [XM]		50.058	
Contact ratio factor [Xeps]		0.268	
Dynamic viscosity (mPa*s) [etaOil]		12.31	
Averaged coefficient of friction [mym]		0.075	
Geometry factor [XBE]		0.220	
Meshing factor [XQ]		1.000	
Tip relief factor [XCa]		1.023	
Integral tooth flank temperature (°C) [theint]		119.58	
Required safety [SSmin]		1.800	
Safety factor for scuffing (intg.-temp.) [SSint]		3.926	
Safety referring to transferred torque [SSL]		8.056	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 --
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm) [As.e/i]		-0.130 / -0.190	-0.095 / -0.145
Number of teeth spanned [k]		10.000	5.000
Base tangent length (no backlash) (mm) [Wk]		175.292	83.617
Actual base tangent length ('span') (mm) [Wk.e/i]		175.169 / 175.113	83.527 / 83.480
Diameter of contact point (mm) [dMWk.m]		441.878	188.314
> Base tangent length Gear 1 is not measurable (Gear too thin)			
Theoretical diameter of ball/pin (mm) [DM]		10.051	10.438
Eff. Diameter of ball/pin (mm) [DMeff]		10.500	10.500

Theor. dim. centre to ball (mm)	[MrK]	228.766	101.181
Actual dimension centre to ball (mm)	[MrK.e/i]	228.595 / 228.516	101.071 / 101.013
Diameter of contact point (mm)	[dMMr.m]	442.960	187.541
Diametral measurement over two balls without clearance (mm)	[MdK]	457.409	202.362
Actual dimension over balls (mm)	[MdK.e/i]	457.067 / 456.909	202.142 / 202.026
Diametral measurement over rolls without clearance (mm)	[MdR]	457.532	202.362
Actual dimension over rolls (mm)	[MdR.e/i]	457.190 / 457.032	202.142 / 202.026
Dimensions over 3 rolls without clearance (mm)	[Md3R]	457.532	0.000
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	457.190 / 457.032	0.000 / 0.000
Chordal tooth thickness (no backlash) (mm)			
	['sn]	8.970	10.269
Actual chordal tooth thickness (mm)	['sn.e/i]	8.840 / 8.780	10.174 / 10.124
Reference chordal height from da.m (mm)	[ha]	5.347	7.276
Tooth thickness (Arc) (mm)	[sn]	8.970	10.273
	(mm) [sn.e/i]	8.840 / 8.780	10.178 / 10.128
Backlash free center distance (mm) [aControl.e/i] 314.693 / 314.543			
Backlash free center distance, allowances (mm)			
	[jta]	-0.307 / -0.457	
Centre distance allowances (mm)	[Aa.e/i]	0.052 / 0.000	
Circumferential backlash from Aa (mm)	[jt Aa.e/i]	0.042 / 0.000	
Radial clearance (mm)	[j _r]	0.509 / 0.307	
Circumferential backlash (transverse section) (mm)	[jt]	0.413 / 0.249	
Torsional angle for fixed gear 1 (°)		0.2550 / 0.1537	
Normal backlash (mm)	[jn]	0.351 / 0.212	

7. GEAR ACCURACY

----- GEAR 1 ----- GEAR 2 --

According to

DIN 3961:1978:

Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	9.00
Single pitch deviation (µm)	[fp]	10.00	9.00
Difference between adjacent pitches (µm)	[fu]	12.00	11.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	35.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	22.00
Concentricity deviation (µm)	[Fr]	28.00	25.00
Tooth Thickness Variation (µm)	[Rs]	16.00	15.00
Total radial composite deviation (µm)	[Fi'']	32.00	28.00
Radial tooth-to-tooth composite deviation (µm)	[fi'']	14.00	12.00
Total tangential composite deviation (µm)	[Fi']	42.00	38.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	15.00

Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)

Maximum value for deviation error of axis (µm)	[fSigbet]	36.00 (Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	106.0	18.5
Mean coeff. of friction (acc. Niemann)	[mum]	0.042	
Wear sliding coef. by Niemann	[zetw]	0.644	
Power loss from gear load (kW)	[PVZ]	2.304	
(Meshing efficiency (%))	[etaz]	99.548)	
Weight - calculated with da (kg)	[Mass]	266.540	51.498
Total weight (kg)	[Mass]	318.037	
Moment of inertia (System referenced to wheel 1):			
calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m ²)	[TraeghMom]	6.07936	0.19332
System ((da+df)/2...di) (kg*m ²)	[TraeghMom]	7.18627	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
- Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
- The calculation is done for the Operating pitch circle..
- Details of calculation method:
 - cg according to method B
 - KV according to method B
 - KHb, KFb according method C
 - KHa, KFa according to method B

End report

lines: 502

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----- Project -----
Name : prevodovka_zkusebna

----- File -----
Name : i56
Changed by : jirisuch on: 14.03.2014 at: 18:07:09

Important hint: At least one warning has occurred during the calculation:

1-> The circumferential speed is very high (22.3165 m/s)!
You have to take adequate action to
guarantee proper lubrication.

2-> Notice:
Gear 1 :
Measuring the Base tangent length is critical,
it is better to use measurement over rolls!

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 --
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	1073.0	1839.4
Torque (Nm)	[T]	4541.0	2648.9
Application factor	[KA]		1.20
Required service life	[H]		20000.00
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 --
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	60	35
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 --
Surface hardness		HRC 56	HRC 56
Fatigue strength. tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofpP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in)		
	[Ca]	3.4	3.4

Lubrication type

oil injection lubrication

Type of oil

Oil: ISO-VG 46

Lubricant base

Mineral-oil base

Kinem. viscosity oil at 40 °C (mm²/s)

[nu40] 46.00

Kinem. viscosity oil at 100 °C (mm²/s)

[nu100] 6.70

FZG test A/8.3/90 (

ISO 14635-1:2006)

[FZGtestA] 12

Specific density at 15 °C (kg/dm³)

[roOil] 0.880

Oil temperature (°C)

[TS] 70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.583	
Gear ratio	[u]	1.714	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	22.122	
	[alfwt.e/i]	22.146 / 22.122	
Working pressure angle at normal section (°)	[alfwn]	20.219	
Helix angle at operating pitch circle (°)	[betaw]	25.037	
Base helix angle (°)	[betab]	23.399	
Reference centre distance (mm)	[ad]	314.463	
Sum of profile shift coefficients	[Summexi]	0.0900	
Profile shift coefficient	[x]	-0.0417	0.1317
Tooth thickness (Arc) (module)	[sn*]	1.5404	1.6667
Tip alteration (mm)	[k*mn]	-0.003	-0.003
Reference diameter (mm)	[d]	397.216	231.709
Base diameter (mm)	[db]	368.603	215.018
Tip diameter (mm)	[da]	408.709	245.284
(mm)	[da.e/i]	408.709 / 408.459	245.284 / 245.274
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.250	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	408.709	245.284
(mm)	[dFa.e/i]	408.709 / 408.459	245.284 / 245.274
Active tip diameter (mm)	[dNa.e/i]	408.709 / 408.459	245.284 / 245.274
Operating pitch diameter (mm)	[dw]	397.895	232.105
(mm)	[dw.e/i]	397.960 / 397.895	232.144 / 232.105
Root diameter (mm)	[df]	381.715	218.290
Generating Profile shift coefficient	[xE.e/i]	-0.0715 / -0.0852	0.1100 / 0.0985
Manufactured root diameter with xE (mm)	[df.e/i]	381.358 / 381.193	218.029 / 217.892
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.876 / 1.631	1.818 / 1.679
Active root diameter (mm)	[dNf]	387.402	223.417
(mm)	[dNf.e/i]	387.494 / 387.402	223.651 / 223.417
Root form diameter (mm)	[dFf]	385.165	222.100

	(mm)	[dFf.e/i]	384.888 / 384.761	221.926 / 221.835
Reserve (dNf-dFf)/2 (mm)		[cF.e/i]	1.366 / 1.257	0.908 / 0.746
Addendum (mm)	[ha = mn * (haP**x)]		5.747	6.787
(mm)		[ha.e/i]	5.747 / 5.622	6.787 / 6.782
Dedendum (mm)	[hf = mn * (hfP*-x)]		7.750	6.710
(mm)		[hf.e/i]	7.929 / 8.011	6.840 / 6.909
Roll angle at dFa (°)		[xsi_dFa.e/i]	27.446 / 27.355	31.452 / 31.446
Roll angle to dNa (°)		[xsi_dNa.e/i]	27.446 / 27.355	31.452 / 31.446
Roll angle to dNf (°)		[xsi_dNf.e/i]	18.577 / 18.531	16.398 / 16.170
Roll angle at dFf (°)		[xsi_dFf.e/i]	17.219 / 17.150	14.639 / 14.541
Tooth height (mm)		[H]	13.497	13.497
Virtual gear no. of teeth		[zn]	78.599	45.849
Normal tooth thickness at tip cyl. (mm)		[san]	4.824	4.492
(mm)		[san.e/i]	4.797 / 4.630	4.397 / 4.340
Normal spacewidth at root cylinder (mm)		[efn]	4.598	4.833
(mm)		[efn.e/i]	4.633 / 4.649	4.878 / 4.902
Max. sliding velocity at tip (m/s)		[vga]	4.075	4.670
Specific sliding at the tip		[zetaa]	0.411	0.411
Specific sliding at the root		[zetaf]	-0.697	-0.697
Sliding factor on tip		[Kga]	0.182	0.209
Sliding factor on root		[Kgf]	-0.209	-0.182
Pitch on reference circle (mm)		[pt]		20.798
Base pitch (mm)		[pbt]		19.300
Transverse pitch on contact-path (mm)		[pet]		19.300
Lead height (mm)		[pz]	2676.111	1561.065
Axial pitch (mm)		[px]		44.602
Length of path of contact (mm)		[ga, e/i]	28.675	(28.675 / 28.237)
Length T1-A, T2-A (mm)		[T1A, T2A]	59.608(59.608/59.757)	59.016(59.016/59.006)
Length T1-B (mm)		[T1B, T2B]	68.983(68.983/68.693)	49.641(49.641/50.069)
Length T1-C (mm)		[T1C, T2C]	74.921(74.921/75.008)	43.704(43.704/43.755)
Length T1-D (mm)		[T1D, T2D]	78.908(78.908/79.057)	39.716(39.716/39.706)
Length T1-E (mm)		[T1E, T2E]	88.283(88.283/87.993)	30.341(30.341/30.769)
Length T1-T2 (mm)		[T1T2]	118.624	(118.624 / 118.762)
Diameter of single contact point B (mm)		[d-B]	393.577(393.577/393.374)	236.833(236.833/237.193)
Diameter of single contact point D (mm)		[d-D]	400.966(400.966/401.083)	229.221(229.221/229.214)
Addendum contact ratio		[eps]	0.692(0.692/ 0.673)	0.793(0.793/ 0.790)
Minimal length of contact line (mm)		[Lmin]		102.560
Transverse contact ratio		[eps_a]		1.486
Transverse contact ratio with allowances		[eps_a.e/m/i]	1.486 / 1.474 / 1.463	
Overlap ratio		[eps_b-beH (eps_b-b)]		1.569 (3.139)
Total contact ratio		[eps_g]		3.055 (4.625)
Total contact ratio with allowances		[eps_g.e/m/i]	3.055/3.044/3.032	(4.625/4.613/4.602)

2. FACTORS OF GENERAL INFLUENCE

		----- GEAR 1 -----	GEAR 2 --
Nominal circum. force at pitch circle (N)		[Ft]	22864.1
Axial force (N)		[Fa]	0.0
Radial force (N)		[Fr]	9182.2
Normal force (N)		[Fnorm]	26846.8
Tangent.load at p.c.d.per mm (N/mm) (N/mm)		[w]	163.32
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)		[Ftw]	22825.1
Axial force (N)		[Faw]	0.0
Radial force (N)		[Frw]	9278.7
Circumferential speed pitch d.. (m/sec)		[v]	22.32
Running-in value (µm)		[yp]	0.8
Running-in value (µm)		[yf]	0.8
Correction coefficient		[CM]	0.800
Gear body coefficient		[CR]	1.000
Reference profile coefficient		[CBS]	0.975
Material coefficient		[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)		[c']	13.329
Meshing stiffness (N/mm/µm)		[cg]	18.185
Reduced mass (kg/mm)		[mRed]	0.14244
Resonance speed (min-1)		[nE1]	1798
Nominal speed (-)		[N]	0.597
Subcritical range			
Running-in value (µm)		[ya]	0.8
Bearing distance l of pinion shaft (mm)		[l]	336.000
Distance s of pinion shaft (mm)		[s]	16.800
Outside diameter of pinion shaft (mm)		[dsh]	168.000
Load according to figure 6.8, DIN 3990-1:1987 [-]			4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)			

Coefficient K' according figure 6.8, DIN 3990-1:1987 [K']		-1.00	
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]	5.12	
from deformation of shaft (µm)	[fsh*B1]	1.14	
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (µm)	[fma*B2]	10.00	
Tooth trace deviation, theoretical (µm)	[Fbx]	6.03	
Running-in value (µm)	[yb]	0.9	
Dynamic factor	[KV]	1.236	
Face load factor - flank	[KHb]	1.192	
- Tooth root	[KFb]	1.153	
- Scuffing	[KBb]	1.192	
Transverse load factor - flank	[KHα]	1.170	
- Tooth root	[KFα]	1.170	
- Scuffing	[KBα]	1.170	
Helical load factor scuffing	[Kbg]	1.287	
Number of load cycles (in mio.)	[NL]	1287.600	2207.314

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	----- GEAR 2 --
Tooth form factor	[YF]	1.21	1.16
Stress correction factor	[YS]	2.38	2.42
Working angle (°)	[alfFen]	19.39	19.54
Bending lever arm (mm)	[hF]	6.06	5.61
Tooth thickness at root (mm)	[sFn]	13.47	13.24
Tooth root radius (mm)	[roF]	2.36	2.35
(hF* = 1.010/0.935 sFn* = 2.245/2.206 roF* = 0.393/0.391 dsFn = 383.54/220.09 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm²)	[sigF0]	61.85	60.33
Tooth root stress (N/mm²)	[sigF]	123.81	120.77
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.003	1.003
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.950	0.950
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm²)	[sigFG]	703.22	702.96
Permissible tooth root stress (N/mm²)	[sigFP=sigFG/SFmin]	502.30	502.11
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	5.68	5.82
Transmittable power (kW)	[kWRating]	2070.11	2121.48

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	----- GEAR 2 --
Zone factor	[ZH]		2.290
Elasticity coefficient (N ^{.5} /mm)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.820	
Helix angle factor	[Zbet]	0.952	
Effective facewidth (mm)	[beff]	70.00	
Nominal flank pressure (N/mm²)	[sigH0]	358.62	
Surface pressure at operating pitch circle (N/mm²)	[sigHw]	515.90	
Single tooth contact factor	[ZB,ZD]	1.00	1.00
Flank pressure (N/mm²)	[sigH]	515.90	515.90
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	1.024	1.024
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000

	[ZL*ZV*ZR*ZNT]	0.947	0.947
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm ²)	[sigHG]	1154.93	1154.93
Permissible surface pressure (N/mm ²) [sigHP=sigHG/SHmin]		1154.93	1154.93
Safety for surface pressure at operating pitch circle			
	[SHw]	2.24	2.24
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	2557.17	2557.17
Safety for stress at single tooth contact			
	[SHBD=sigHG/sigH]	2.24	2.24
(Safety regarding nominal torque)	[(SHBD)^2]	5.01	5.01

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)			
	[XWrelT]	1.000	
Thermal contact factor (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	3.40	3.40
Optimal tip relief (µm)	[Ceff]		7.18
Effective facewidth (mm)	[beff]		70.000
Applicable circumferential force/facewidth (N/mm)			
	[wBt]	434.818	
Pressure angle factor (eps1: 0.692, eps2: 0.793)	[Xalfbet]		0.990
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	83.51	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	23.96	
Scuffing temperature (°C)	[theS]	469.40	
Coordinate gamma (point of highest temp.)	[Gamma]	0.136	
[Gamma.A]= -0.204 [Gamma.E]= 0.178			
Highest contact temp. (°C)	[theB]	107.47	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} *mm)	[XM]	50.058	
Geometry factor	[XB]	0.077	
Load sharing factor	[XGam]	1.000	
Dynamic viscosity (mPa*s)	[etaM]	8.38	
Coefficient of friction	[mym]	0.059	
Required safety	[SBmin]	2.000	
Safety factor for scuffing (flash-temp)	[SB]	10.655	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	82.50	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	14.88	
Integral scuffing temperature (°C)	[theSint]	469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} *mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.271	
Dynamic viscosity (mPa*s)	[etaOil]	12.31	
Averaged coefficient of friction	[mym]	0.054	
Geometry factor	[XBE]	0.195	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.021	
Integral tooth flank temperature (°C)	[theint]	104.82	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	4.478	
Safety referring to transferred torque	[SSL]	11.471	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 -----
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.095 / -0.145
Number of teeth spanned	[k]	9.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	157.057	101.851
Actual base tangent length ('span') (mm)	[Wk.e/i]	156.935 / 156.878	101.762 / 101.715
Diameter of contact point (mm)	[dMwk.m]	395.733	234.417

Theoretical diameter of ball/pin (mm)	[DM]	10.080	10.282
Eff. Diameter of ball/pin (mm)	[DMeff]	10.500	10.500
Theor. dim. centre to ball (mm)	[MrK]	205.945	124.078
Actual dimension centre to ball (mm)	[MrK.e/i]	205.776 / 205.698	123.963 / 123.903
Diameter of contact point (mm)	[dMMr.m]	397.280	233.448
Diametral measurement over two balls without clearance (mm)	[MdK]	411.889	247.917
Actual dimension over balls (mm)	[MdK.e/i]	411.552 / 411.396	247.688 / 247.567
Diametral measurement over rolls without clearance (mm)	[MdR]	411.889	248.156
Actual dimension over rolls (mm)	[MdR.e/i]	411.552 / 411.396	247.927 / 247.806
Dimensions over 3 rolls without clearance (mm)	[Md3R]	0.000	248.156
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	0.000 / 0.000	247.927 / 247.806
Chordal tooth thickness (no backlash) (mm)	['sn]	9.242	9.998
Actual chordal tooth thickness (mm)	['sn.e/i]	9.112 / 9.052	9.903 / 9.853
Reference chordal height from da.m (mm)	[ha]	5.728	6.874
Tooth thickness (Arc) (mm)	[sn]	9.243	10.000
(mm)	[sn.e/i]	9.113 / 9.053	9.905 / 9.855
Backlash free center distance (mm)	[aControl.e/i]	314.693	/314.543
Backlash free center distance, allowances (mm)	[jta]	-0.307	/ -0.457
Centre distance allowances (mm)	[Aa.e/i]	0.052	/ 0.000
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.042	/ 0.000
Radial clearance (mm)	[jrr]	0.509	/ 0.307
Circumferential backlash (transverse section) (mm)	[jt]	0.413	/ 0.249
Torsional angle for fixed gear 1 (°)		0.2040	/0.1230
Normal backlash (mm)	[jnn]	0.351	/ 0.212

7. GEAR ACCURACY

		----- GEAR 1 -----	GEAR 2 --
According to			
DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	9.00
Single pitch deviation (µm)	[fp]	10.00	9.00
Difference between adjacent pitches (µm)	[fu]	12.00	11.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	35.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	22.00
Concentricity deviation (µm)	[Fr]	28.00	25.00
Tooth Thickness Variation (µm)	[Rs]	16.00	15.00
Total radial composite deviation (µm)	[Fi'']	32.00	28.00
Radial tooth-to-tooth composite deviation (µm)	[fi'']	14.00	12.00
Total tangential composite deviation (µm)	[Fi']	42.00	38.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	15.00
Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)			
Maximum value for deviation error of axis (µm)	[fSigbet]	36.00	(Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00	

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	86.5	29.4
Mean coeff. of friction (acc. Niemann)	[mum]		0.029
Wear sliding coef. by Niemann	[zetw]		0.610
Power loss from gear load (kW)	[PVZ]		1.407
(Meshing efficiency (%))	[etaz]		99.724
Weight - calculated with da (kg)	[Mass]	215.725	77.698
Total weight (kg)	[Mass]		293.423
Moment of inertia (System referenced to wheel 1): calculation without consideration of the exact tooth shape			

single gears	$((da+df)/2...di)$	$(kg*m^2)$	[TraeghMom]	3.92701	0.46461
System	$((da+df)/2...di)$	$(kg*m^2)$	[TraeghMom]	5.29238	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
The calculation is done for the Operating pitch circle..
- Details of calculation method:
cg according to method B
KV according to method B
KHb, KFb according method C
KHa, KFa according to method B

End report lines: 501

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----- Project -----
Name : prevodovka_zkusebna

----- File -----
Name : i65
Changed by : jirisuch on: 14.03.2014 at: 18:08:18

Important hint: At least one warning has occurred during the calculation:

1-> Notice:
Gear 1 :
Measuring the Base tangent length is critical,
it is better to use measurement over rolls!

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 --
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	625.9	1073.0
Torque (Nm)	[T]	7784.6	4541.0
Application factor	[KA]		1.20
Required service life	[H]		20000.00
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 --
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	60	35
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 --
Surface hardness		HRC 56	HRC 56
Fatigue strength. tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C
Dedendum coefficient [hfP*] 1.250
Root radius factor [rhofP*] 0.250
Addendum coefficient [haP*] 1.000

Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hFP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hFP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofpP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in)	[Ca]	3.4	3.4
-----------------	------------------------	------	-----	-----

Lubrication type	oil injection lubrication	
Type of oil	Oil: ISO-VG 46	
Lubricant base	Mineral-oil base	
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	46.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	6.70
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.880
Oil temperature (°C)	[TS]	70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.583	
Gear ratio	[u]	1.714	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	22.122	
Working pressure angle at normal section (°) [alfwn]	[alfwt.e/i]	22.146 / 22.122	
Helix angle at operating pitch circle (°)	[betaw]	20.219	
Base helix angle (°)	[betab]	25.037	
Reference centre distance (mm)	[ad]	23.399	
Sum of profile shift coefficients	[Summexi]	314.463	
Profile shift coefficient	[x]	0.0900	
Tooth thickness (Arc) (module)	[sn*]	-0.0417	0.1317
Tip alteration (mm)	[k*mn]	1.5404	1.6667
Reference diameter (mm)	[d]	-0.003	-0.003
Base diameter (mm)	[db]	397.216	231.709
Tip diameter (mm)	[da]	368.603	215.018
(mm)	[da.e/i]	408.709	245.284
Tip diameter allowances (mm)	[Ada.e/i]	408.709 / 408.459	245.284 / 245.274
Tip chamfer / tip rounding (mm)	[hK]	0.000 / -0.250	0.000 / -0.010
Tip form diameter (mm)	[dFa]	0.000	0.000
(mm)	[dFa.e/i]	408.709	245.284
Active tip diameter (mm)	[dNa.e/i]	408.709 / 408.459	245.284 / 245.274
Operating pitch diameter (mm)	[dw]	397.895	232.105
(mm)	[dw.e/i]	397.960 / 397.895	232.144 / 232.105
Root diameter (mm)	[df]	381.715	218.290
Generating Profile shift coefficient	[xE.e/i]	-0.0715 / -0.0852	0.1100 / 0.0985
Manufactured root diameter with xE (mm)	[df.e/i]	381.358 / 381.193	218.029 / 217.892
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.876 / 1.631	1.818 / 1.679
Active root diameter (mm)	[dNf]	387.402	223.417
(mm)	[dNf.e/i]	387.494 / 387.402	223.651 / 223.417
Root form diameter (mm)	[dFf]	385.165	222.100
(mm)	[dFf.e/i]	384.888 / 384.761	221.926 / 221.835
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	1.366 / 1.257	0.908 / 0.746
Addendum (mm)	[ha = mn * (haP*+x)]	5.747	6.787
(mm)	[ha.e/i]	5.747 / 5.622	6.787 / 6.782

Dedendum (mm)	[hf = mn * (hfP*-x)]	7.750	6.710
(mm)	[hf.e/i]	7.929 / 8.011	6.840 / 6.909
Roll angle at dFa (°)	[xsi_dFa.e/i]	27.446 / 27.355	31.452 / 31.446
Roll angle to dNa (°)	[xsi_dNa.e/i]	27.446 / 27.355	31.452 / 31.446
Roll angle to dNf (°)	[xsi_dNf.e/i]	18.577 / 18.531	16.398 / 16.170
Roll angle at dFf (°)	[xsi_dFf.e/i]	17.219 / 17.150	14.639 / 14.541
Tooth height (mm)	[H]	13.497	13.497
Virtual gear no. of teeth	[zn]	78.599	45.849
Normal tooth thickness at tip cyl. (mm)	[san]	4.824	4.492
(mm)	[san.e/i]	4.797 / 4.630	4.397 / 4.340
Normal spacewidth at root cylinder (mm)	[efn]	4.598	4.833
(mm)	[efn.e/i]	4.633 / 4.649	4.878 / 4.902
Max. sliding velocity at tip (m/s)	[vga]	2.377	2.724
Specific sliding at the tip	[zetaa]	0.411	0.411
Specific sliding at the root	[zetaf]	-0.697	-0.697
Sliding factor on tip	[Kga]	0.182	0.209
Sliding factor on root	[Kgf]	-0.209	-0.182
Pitch on reference circle (mm)	[pt]		20.798
Base pitch (mm)	[pbt]		19.300
Transverse pitch on contact-path (mm)	[pet]		19.300
Lead height (mm)	[pz]	2676.111	1561.065
Axial pitch (mm)	[px]		44.602
Length of path of contact (mm)	[ga, e/i]	28.675	(28.675 / 28.237)
Length T1-A, T2-A (mm)	[T1A, T2A]	59.608(59.608/59.757)	59.016(59.016/59.006)
Length T1-B (mm)	[T1B, T2B]	68.983(68.983/68.693)	49.641(49.641/50.069)
Length T1-C (mm)	[T1C, T2C]	74.921(74.921/75.008)	43.704(43.704/43.755)
Length T1-D (mm)	[T1D, T2D]	78.908(78.908/79.057)	39.716(39.716/39.706)
Length T1-E (mm)	[T1E, T2E]	88.283(88.283/87.993)	30.341(30.341/30.769)
Length T1-T2 (mm)	[T1T2]	118.624	(118.624 / 118.762)
Diameter of single contact point B (mm)	[d-B]	393.577(393.577/393.374)	236.833(236.833/237.193)
Diameter of single contact point D (mm)	[d-D]	400.966(400.966/401.083)	229.221(229.221/229.214)
Addendum contact ratio	[eps]	0.692(0.692/ 0.673)	0.793(0.793/ 0.790)
Minimal length of contact line (mm)	[Lmin]		102.560
Transverse contact ratio	[eps_a]		1.486
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.486	/ 1.474 / 1.463
Overlap ratio	[eps_b-beH (eps_b-b)]		1.569 (3.139)
Total contact ratio	[eps_g]		3.055 (4.625)
Total contact ratio with allowances	[eps_g.e/m/i]	3.055/3.044/3.032	(4.625/4.613/4.602)

2. FACTORS OF GENERAL INFLUENCE

	----- GEAR 1 -----	GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]	39195.7
Axial force (N)	[Fa]	0.0
Radial force (N)	[Fr]	15740.8
Normal force (N)	[Fnorm]	46023.2
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]	279.97
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	39128.8
Axial force (N)	[Faw]	0.0
Radial force (N)	[Frw]	15906.3
Circumferential speed pitch d.. (m/sec)	[v]	13.02
Running-in value (µm)	[yp]	0.8
Running-in value (µm)	[yf]	0.8
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	13.329
Meshing stiffness (N/mm/µm)	[cg]	18.185
Reduced mass (kg/mm)	[mRed]	0.14244
Resonance speed (min-1)	[nE1]	1798
Nominal speed (-)	[N]	0.348
Subcritical range		
Running-in value (µm)	[ya]	0.8
Bearing distance l of pinion shaft (mm)	[l]	336.000
Distance s of pinion shaft (mm)	[s]	16.800
Outside diameter of pinion shaft (mm)	[dsh]	168.000
Load according to figure 6.8, DIN 3990-1:1987 [-]		4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)		
Coefficient K' according figure 6.8, DIN 3990-1:1987 [K']		-1.00
Without support effect		
Tooth trace deviation (active) (µm)	[Fby]	4.46

from deformation of shaft (μm)	[fsh*B1]		1.72
Tooth without tooth trace modification			
Position of Contact pattern: favorable			
from production tolerances (μm)	[fma*B2]		10.00
Tooth trace deviation, theoretical (μm)	[Fbx]		5.25
Running-in value (μm)	[yb]		0.8
Dynamic factor	[KV]		1.090
Face load factor - flank	[KHb]		1.111
- Tooth root	[KFb]		1.089
- Scuffing	[KBb]		1.111
Transverse load factor - flank	[KHa]		1.092
- Tooth root	[KFa]		1.092
- Scuffing	[KBa]		1.092
Helical load factor scuffing	[Kbg]		1.287
Number of load cycles (in mio.)	[NL]	751.100	1287.600

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	GEAR 2 --
Tooth form factor	[YF]	1.21	1.16
Stress correction factor	[YS]	2.38	2.42
Working angle ($^\circ$)	[alfFen]	19.39	19.54
Bending lever arm (mm)	[hF]	6.06	5.61
Tooth thickness at root (mm)	[sFn]	13.47	13.24
Tooth root radius (mm)	[roF]	2.36	2.35
(hF* = 1.010/0.935 sFn* = 2.245/2.206 roF* = 0.393/0.391 dsFn = 383.54/220.09 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm^2)			
Tooth root stress (N/mm^2)	[sigF0] [sigF]	106.02 164.85	103.42 160.80
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	1.003	1.003
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.950	0.950
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm^2)	[sigFG]	703.22	702.96
Permissible tooth root stress (N/mm^2)	[sigFP=sigFG/SFmin]	502.30	502.11
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	4.27	4.37
Transmittable power (kW)	[kWRating]	1554.72	1593.30

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	GEAR 2 --
Zone factor	[ZH]		2.290
Elasticity coefficient ($\text{N}^{.5}/\text{mm}$)	[ZE]	189.812	
Contact ratio factor	[Zeps]	0.820	
Helix angle factor	[Zbet]	0.952	
Effective facewidth (mm)	[beff]	70.00	
Nominal flank pressure (N/mm^2)	[sigH0]	469.54	
Surface pressure at operating pitch circle (N/mm^2)	[sigHw]	591.33	
Single tooth contact factor	[ZB, ZD]	1.00	1.00
Flank pressure (N/mm^2)	[sigH]	591.33	591.33
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	1.008	1.008
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	0.932	0.932
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm^2)	[sigHG]	1136.75	1136.75

Permissible surface pressure (N/mm ²) [sigHP=sigHG/SHmin]	1136.75	1136.75
Safety for surface pressure at operating pitch circle		
Required safety [SHw]	1.92	1.92
[SHmin]	1.00	1.00
Transmittable power (kW) [kWRating]	1885.58	1885.58
Safety for stress at single tooth contact		
(Safety regarding nominal torque) [SHBD=sigHG/sigH]	1.92	1.92
[(SHBD)^2]	3.70	3.70

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)			
[XWrelT]	1.000		
Thermal contact factor (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	3.40	3.40
Optimal tip relief (µm)	[Ceff]	12.32	
Effective facewidth (mm)	[beff]	70.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	571.273	
Pressure angle factor (eps1: 0.692, eps2: 0.793)	[Xalfbet]	0.990	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	85.74	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	27.90	
Scuffing temperature (°C)	[theS]	469.40	
Coordinate gamma (point of highest temp.)	[Gamma]	0.136	
[Gamma.A]= -0.204 [Gamma.E]= 0.178			
Highest contact temp. (°C)	[theB]	113.64	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Geometry factor	[XB]	0.077	
Load sharing factor	[XGam]	1.000	
Dynamic viscosity (mPa*s)	[etaM]	7.92	
Coefficient of friction	[mym]	0.073	
Required safety	[SBmin]	2.000	
Safety factor for scuffing (flash-temp)	[SB]	9.149	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	84.35	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	17.08	
Integral scuffing temperature (°C)	[theSint]	469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.271	
Dynamic viscosity (mPa*s)	[etaOil]	12.31	
Averaged coefficient of friction	[mym]	0.067	
Geometry factor	[XBE]	0.195	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.021	
Integral tooth flank temperature (°C)	[theint]	109.98	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	4.268	
Safety referring to transferred torque	[SSL]	9.991	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 --
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.095 / -0.145
Number of teeth spanned	[k]	9.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	157.057	101.851
Actual base tangent length ('span') (mm)	[Wk.e/i]	156.935 / 156.878	101.762 / 101.715
Diameter of contact point (mm)	[dMWk.m]	395.733	234.417
Theoretical diameter of ball/pin (mm)	[DM]	10.080	10.282
Eff. Diameter of ball/pin (mm)	[DMeff]	10.500	10.500
Theor. dim. centre to ball (mm)	[MrK]	205.945	124.078

Actual dimension centre to ball (mm)	[MrK.e/i]	205.776 / 205.698	123.963 / 123.903
Diameter of contact point (mm)	[dMMr.m]	397.280	233.448
Diametral measurement over two balls without clearance (mm)	[MdK]	411.889	247.917
Actual dimension over balls (mm)	[MdK.e/i]	411.552 / 411.396	247.688 / 247.567
Diametral measurement over rolls without clearance (mm)	[MdR]	411.889	248.156
Actual dimension over rolls (mm)	[MdR.e/i]	411.552 / 411.396	247.927 / 247.806
Dimensions over 3 rolls without clearance (mm)	[Md3R]	0.000	248.156
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	0.000 / 0.000	247.927 / 247.806
Chordal tooth thickness (no backlash) (mm)	['sn]	9.242	9.998
Actual chordal tooth thickness (mm)	['sn.e/i]	9.112 / 9.052	9.903 / 9.853
Reference chordal height from da.m (mm)	[ha]	5.728	6.874
Tooth thickness (Arc) (mm)	[sn]	9.243	10.000
	(mm) [sn.e/i]	9.113 / 9.053	9.905 / 9.855
Backlash free center distance (mm)	[aControl.e/i]	314.693	/314.543
Backlash free center distance, allowances (mm)	[jta]	-0.307	/ -0.457
Centre distance allowances (mm)	[Aa.e/i]	0.052	/ 0.000
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.042	/ 0.000
Radial clearance (mm)	[jr]	0.509	/ 0.307
Circumferential backlash (transverse section) (mm)	[jt]	0.413	/ 0.249
Torsional angle for fixed gear 1 (°)		0.2040	/0.1230
Normal backlash (mm)	[jn]	0.351	/ 0.212

7. GEAR ACCURACY

		----- GEAR 1 -----	----- GEAR 2 --
According to			
DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[fffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	9.00
Single pitch deviation (µm)	[fp]	10.00	9.00
Difference between adjacent pitches (µm)	[fu]	12.00	11.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	35.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	22.00
Concentricity deviation (µm)	[Fr]	28.00	25.00
Tooth Thickness Variation (µm)	[Rs]	16.00	15.00
Total radial composite deviation (µm)	[Fi"]	32.00	28.00
Radial tooth-to-tooth composite deviation (µm)	[fi"]	14.00	12.00
Total tangential composite deviation (µm)	[Fi']	42.00	38.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	15.00
Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)			
Maximum value for deviation error of axis (µm)	[fSigbet]	36.00	(Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00	

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	86.5	29.4
Mean coeff. of friction (acc. Niemann)	[mum]		0.035
Wear sliding coef. by Niemann	[zetw]		0.610
Power loss from gear load (kW)	[PVZ]		1.745
(Meshing efficiency (%))	[etaz]		99.658)
Weight - calculated with da (kg)	[Mass]	215.725	77.698
Total weight (kg)	[Mass]		293.423
Moment of inertia (System referenced to wheel 1):			
calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	3.92701	0.46461
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	5.29238	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
The calculation is done for the Operating pitch circle..
- Details of calculation method:
cg according to method B
KV according to method B
KHb, KFb according method C
KHa, KFa according to method B

End report

lines: 501

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Name : prevodovka_zkusebna

----- File -----
Name : i78
Changed by : jirisuch on: 14.03.2014 at: 18:09:09

Important hint: At least one warning has occurred during the calculation:

1-> The circumferential speed is very high (20.0848 m/s)!
You have to take adequate action to
guarantee proper lubrication.

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:

Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 --
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	1073.0	1347.5
Torque (Nm)	[T]	4541.0	3616.0
Application factor	[KA]		1.20
Required service life	[H]		20000.00
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 --
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	54	43
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 --
Surface hardness		HRC 56	HRC 56
Fatigue strength. tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000

Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Tool or reference profile of gear 2 :
Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in)		
	[Ca]	3.4	3.4

Lubrication type	oil injection lubrication
Type of oil	Oil: ISO-VG 46
Lubricant base	Mineral-oil base
Kinem. viscosity oil at 40 °C (mm ² /s)	[nu40] 46.00
Kinem. viscosity oil at 100 °C (mm ² /s)	[nu100] 6.70
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA] 12
Specific density at 15 °C (kg/dm ³)	[roOil] 0.880
Oil temperature (°C)	[TS] 70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.796	
Gear ratio	[u]	1.256	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	18.935	
	[alfwt.e/i]	18.963 / 18.935	
Working pressure angle at normal section (°)	[alfwn]	17.326	
Helix angle at operating pitch circle (°)			
Base helix angle (°)	[betaw]	24.583	
Reference centre distance (mm)	[betab]	23.399	
	[ad]	321.083	
Sum of profile shift coefficients	[Summexi]	-0.9504	
Profile shift coefficient	[x]	-0.5834	-0.3670
Tooth thickness (Arc) (module)	[sn*]	1.1461	1.3036
Tip alteration (mm)	[k*mn]	-0.380	-0.380
Reference diameter (mm)	[d]	357.494	284.672
Base diameter (mm)	[db]	331.742	264.165
Tip diameter (mm)	[da]	361.733	291.507
(mm)	[da.e/i]	361.733 / 361.503	291.507 / 291.497
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.230	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	361.733	291.507
(mm)	[dFa.e/i]	361.733 / 361.503	291.507 / 291.497
Active tip diameter (mm)	[dNa.e/i]	361.733 / 361.503	291.507 / 291.497
Operating pitch diameter (mm)	[dw]	350.722	279.278
(mm)	[dw.e/i]	350.780 / 350.722	279.324 / 279.278
Root diameter (mm)	[df]	335.493	265.267
Generating Profile shift coefficient	[xE.e/i]	-0.6132 / -0.6269	-0.3968 / -0.4105
Manufactured root diameter with xE (mm)	[df.e/i]	335.136 / 334.971	264.910 / 264.745
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.928 / 1.678	1.818 / 1.678
Active root diameter (mm)	[dNf]	341.530	270.943
(mm)	[dNf.e/i]	341.611 / 341.530	271.144 / 270.943
Root form diameter (mm)	[dFf]	341.132	270.743
(mm)	[dFf.e/i]	340.910 / 340.808	270.534 / 270.439
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.402 / 0.310	0.352 / 0.204
Addendum (mm)	[ha = mn * (haP**x)]	2.119	3.418
(mm)	[ha.e/i]	2.119 / 2.004	3.418 / 3.413
Dedendum (mm)	[hf = mn * (hfP**-x)]	11.001	9.702

(mm)	[hf.e/i]	11.179 / 11.262	9.881 / 9.963
Roll angle at dFa (°)	[xsi_dFa.e/i]	24.908 / 24.808	26.735 / 26.729
Roll angle to dNa (°)	[xsi_dNa.e/i]	24.908 / 24.808	26.735 / 26.729
Roll angle to dNf (°)	[xsi_dNf.e/i]	14.079 / 14.020	13.256 / 13.062
Roll angle at dFf (°)	[xsi_dFf.e/i]	13.563 / 13.486	12.657 / 12.562
Tooth height (mm)	[H]	13.120	13.120
Virtual gear no. of teeth	[zn]	70.739	56.329
Normal tooth thickness at tip cyl. (mm)	[san]	5.330	5.262
(mm)	[san.e/i]	5.287 / 5.138	5.133 / 5.068
Normal spacewidth at root cylinder (mm)	[efn]	5.645	5.664
(mm)	[efn.e/i]	5.715 / 5.748	5.753 / 5.796
Max. sliding velocity at tip (m/s)	[vga]	3.853	4.136
Specific sliding at the tip	[zetaa]	0.476	0.476
Specific sliding at the root	[zetaf]	-0.907	-0.907
Sliding factor on tip	[Kga]	0.196	0.210
Sliding factor on root	[Kgf]	-0.210	-0.196
Pitch on reference circle (mm)	[pt]		20.798
Base pitch (mm)	[pbt]		19.300
Transverse pitch on contact-path (mm)	[pet]		19.300
Lead height (mm)	[pz]	2408.500	1917.880
Axial pitch (mm)	[px]		44.602
Length of path of contact (mm)	[ga, e/i]	31.520	(31.520 / 31.059)
Length T1-A, T2-A (mm)	[T1A, T2A]	40.588(40.588/40.760)	61.631(61.631/61.619)
Length T1-B (mm)	[T1B, T2B]	52.808(52.808/52.519)	49.411(49.411/49.860)
Length T1-C (mm)	[T1C, T2C]	56.905(56.905/56.994)	45.313(45.313/45.384)
Length T1-D (mm)	[T1D, T2D]	59.888(59.888/60.060)	42.331(42.331/42.319)
Length T1-E (mm)	[T1E, T2E]	72.108(72.108/71.819)	30.111(30.111/30.560)
Length T1-T2 (mm)	[T1T2]	102.218	(102.218 / 102.378)
Diameter of single contact point B (mm)	[d-B]	348.149(348.149/347.974)	282.044(282.044/282.360)
Diameter of single contact point D (mm)	[d-D]	352.703(352.703/352.820)	277.400(277.400/277.393)
Addendum contact ratio	[eps]	0.788(0.788/ 0.768)	0.845(0.845/ 0.841)
Minimal length of contact line (mm)	[Lmin]		116.888
Transverse contact ratio	[eps_a]		1.633
Transverse contact ratio with allowances	[eps_a.e/m/i]	1.633 / 1.621 / 1.609	
Overlap ratio	[eps_b-beH (eps_b-b)]		1.569 (3.139)
Total contact ratio	[eps_g]		3.203 (4.772)
Total contact ratio with allowances	[eps_g.e/m/i]	3.203/3.191/3.179	(4.772/4.760/4.748)

2. FACTORS OF GENERAL INFLUENCE

		----- GEAR 1 -----	----- GEAR 2 --
Nominal circum. force at pitch circle (N)	[Ft]		25404.6
Axial force (N)	[Fa]		0.0
Radial force (N)	[Fr]		10202.4
Normal force (N)	[Fnorm]		29829.8
Tangent.load at p.c.d.per mm (N/mm) (N/mm)	[w]		181.46
Only as information: Forces at operating pitch circle:			
Nominal circumferential force (N)	[Ftw]		25895.2
Axial force (N)	[Faw]		0.0
Radial force (N)	[Frw]		8883.8
Circumferential speed pitch d.. (m/sec)	[v]		20.08
Running-in value (µm)	[yp]		0.8
Running-in value (µm)	[yf]		0.8
Correction coefficient	[CM]		0.800
Gear body coefficient	[CR]		1.000
Reference profile coefficient	[CBS]		0.975
Material coefficient	[E/Est]		1.000
Singular tooth stiffness (N/mm/µm)	[c']		11.555
Meshing stiffness (N/mm/µm)	[cg]		17.042
Reduced mass (kg/mm)	[mRed]		0.16124
Resonance speed (min-1)	[nE1]		1818
Nominal speed (-)	[N]		0.590
Subcritical range			
Running-in value (µm)	[ya]		0.8
Bearing distance l of pinion shaft (mm)	[l]		336.000
Distance s of pinion shaft (mm)	[s]		16.800
Outside diameter of pinion shaft (mm)	[dsh]		168.000
Load according to figure 6.8, DIN 3990-1:1987	[-]		4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)			
Coefficient K' according figure 6.8, DIN 3990-1:1987	[K']		-1.00
Without support effect			
Tooth trace deviation (active) (µm)	[Fby]		5.66
from deformation of shaft (µm)	[fsh*B1]		0.66

Tooth without tooth trace modification			
Position of Contact pattern: favorable from production tolerances (μm)	[fma*B2]		10.00
Tooth trace deviation, theoretical (μm)	[Fbx]		6.66
Running-in value (μm)	[yB]		1.0
Dynamic factor	[KV]		1.184
Face load factor - flank	[KHb]		1.187
- Tooth root	[KFb]		1.150
- Scuffing	[KBb]		1.187
Transverse load factor - flank	[KHa]		1.142
- Tooth root	[KFa]		1.142
- Scuffing	[KBa]		1.142
Helical load factor scuffing	[Kbg]		1.294
Number of load cycles (in mio.)	[NL]	1287.600	1616.986

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	GEAR 2 --
Tooth form factor	[YF]	1.23	1.17
Stress correction factor	[YS]	2.01	2.11
Working angle ($^\circ$)	[alfFen]	16.01	16.04
Bending lever arm (mm)	[hF]	5.22	5.00
Tooth thickness at root (mm)	[sFn]	12.51	12.56
Tooth root radius (mm)	[roF]	3.37	3.15
(hF* = 0.869/0.833 sFn* = 2.086/2.093 roF* = 0.562/0.525 dsFn = 337.80/267.46 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm^2)			
	[sigF0]	59.03	59.00
Tooth root stress (N/mm^2)	[sigF]	110.11	110.06
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	0.994	0.995
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.941	0.942
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm^2)	[sigFG]	696.38	697.40
Permissible tooth root stress (N/mm^2)			
	[sigFP=sigFG/SFmin]	497.42	498.14
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	6.32	6.34
Transmittable power (kW)	[kWRating]	2305.00	2309.51

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	GEAR 2 --
Zone factor	[ZH]		2.493
Elasticity coefficient ($\text{N}^{.5}/\text{mm}$)	[ZE]		189.812
Contact ratio factor	[Zeps]		0.783
Helix angle factor	[Zbet]		0.952
Effective facewidth (mm)	[beff]		70.00
Nominal flank pressure (N/mm^2)	[sigH0]		377.15
Surface pressure at operating pitch circle (N/mm^2)			
	[sigHw]		523.34
Single tooth contact factor	[ZB, ZD]	1.00	1.00
Flank pressure (N/mm^2)	[sigH]	523.34	523.34
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	1.021	1.021
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	0.944	0.944
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm^2)	[sigHG]	1151.35	1151.35
Permissible surface pressure (N/mm^2) [sigHP=sigHG/SHmin]		1151.35	1151.35

Safety for surface pressure at operating pitch circle	[SHw]	2.20	2.20
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	2469.55	2469.55
Safety for stress at single tooth contact	[SHBD=sigHG/sigH]	2.20	2.20
(Safety regarding nominal torque)	[(SHBD)^2]	4.84	4.84

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	3.40	3.40
Optimal tip relief (µm)	[Ceff]	8.52	
Effective facewidth (mm)	[beff]	70.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	452.145	
Pressure angle factor (eps1: 0.788, eps2: 0.845)	[Xalfbet]	0.944	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	85.23	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	27.00	
Scuffing temperature (°C)	[theS]	469.40	
Coordinate gamma (point of highest temp.)	[Gamma]	-0.335	
[Gamma.A]= -0.287 [Gamma.E]= 0.267			
Highest contact temp. (°C)	[theB]	112.22	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Geometry factor	[XB]	0.235	
Load sharing factor	[XGam]	0.333	
Dynamic viscosity (mPa*s)	[etaM]	8.02	
Coefficient of friction	[mym]	0.070	
Required safety	[SBmin]	2.000	
Safety factor for scuffing (flash-temp)	[SB]	9.457	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	84.24	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	16.95	
Integral scuffing temperature (°C)	[theSint]	469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.252	
Dynamic viscosity (mPa*s)	[etaOil]	12.31	
Averaged coefficient of friction	[mym]	0.060	
Geometry factor	[XBE]	0.235	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.027	
Integral tooth flank temperature (°C)	[theint]	109.67	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	4.280	
Safety referring to transferred torque	[SSL]	10.068	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 --
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.130 / -0.190
Number of teeth spanned	[k]	7.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	118.741	100.694
Actual base tangent length ('span') (mm)	[Wk.e/i]	118.619 / 118.562	100.571 / 100.515
Diameter of contact point (mm)	[dMwk.m]	349.140	279.818
Theoretical diameter of ball/pin (mm)	[DM]	9.951	9.953
Eff. Diameter of ball/pin (mm)	[DMeff]	10.000	10.000
Theor. dim. centre to ball (mm)	[MrK]	181.854	146.799
Actual dimension centre to ball (mm)	[MrK.e/i]	181.662 / 181.572	146.615 / 146.530

Diameter of contact point (mm)	[dMMr.m]	350.187	279.973
Diametral measurement over two balls without clearance (mm)	[MdK]	363.708	293.409
Actual dimension over balls (mm)	[MdK.e/i]	363.323 / 363.144	293.042 / 292.871
Diametral measurement over rolls without clearance (mm)	[MdR]	363.708	293.598
Actual dimension over rolls (mm)	[MdR.e/i]	363.323 / 363.144	293.231 / 293.060
Dimensions over 3 rolls without clearance (mm)	[Md3R]	0.000	293.598
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	0.000 / 0.000	293.231 / 293.060
Chordal tooth thickness (no backlash) (mm)	['sn]	6.876	7.821
Actual chordal tooth thickness (mm)	['sn.e/i]	6.746 / 6.686	7.691 / 7.631
Reference chordal height from da.m (mm)	[ha]	2.089	3.460
Tooth thickness (Arc) (mm)	[sn]	6.877	7.822
(mm)	[sn.e/i]	6.747 / 6.687	7.692 / 7.632
Backlash free center distance (mm)	[aControl.e/i]	314.588	/314.396
Backlash free center distance, allowances (mm)	[jta]	-0.412	/ -0.604
Centre distance allowances (mm)	[Aa.e/i]	0.052	/ 0.000
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.036	/ 0.000
Radial clearance (mm)	[j_r]	0.656	/ 0.412
Circumferential backlash (transverse section) (mm)	[jt]	0.447	/ 0.281
Torsional angle for fixed gear 1 (°)		0.1799	/0.1133
Normal backlash (mm)	[j_n]	0.381	/ 0.240

7. GEAR ACCURACY

		----- GEAR 1 -----	GEAR 2 --
According to			
DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ff_b]	8.00	8.00
Helix slope deviation (µm)	[fH_b]	10.00	10.00
Total helix deviation (µm)	[F_b]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	10.00
Single pitch deviation (µm)	[fp]	10.00	10.00
Difference between adjacent pitches (µm)	[fu]	12.00	12.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	40.00
Cumulative circular pitch deviation over z/8 pitches (µm)	[Fpz/8]	25.00	25.00
Concentricity deviation (µm)	[Fr]	28.00	28.00
Tooth Thickness Variation (µm)	[Rs]	16.00	16.00
Total radial composite deviation (µm)	[Fi'']	32.00	32.00
Radial tooth-to-tooth composite deviation (µm)	[fi'']	14.00	14.00
Total tangential composite deviation (µm)	[Fi']	42.00	42.00
Tangential tooth-to-tooth composite deviation (µm)	[fi']	16.00	16.00
Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)			
Maximum value for deviation error of axis (µm)	[fSigbet]	36.00	(Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00	

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	65.6	41.6
Mean coeff. of friction (acc. Niemann)	[mum]	0.030	
Wear sliding coef. by Niemann	[zetw]	0.777	
Power loss from gear load (kW)	[PVZ]	1.521	
(Meshing efficiency (%))	[etaz]	99.702	
Weight - calculated with da (kg)	[Mass]	168.985	109.741
Total weight (kg)	[Mass]	278.726	
Moment of inertia (System referenced to wheel 1): calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m ²)	[TraeghMom]	2.37670	0.96648
System ((da+df)/2...di) (kg*m ²)	[TraeghMom]	3.90090	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with consideration of all tolerances
- Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
- The calculation is done for the Operating pitch circle..
- Details of calculation method:
 - cg according to method B
 - KV according to method B
 - KHb, KFb according method C
 - KHa, KFa according to method B

End report

lines: 501

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----- File -----
Name : i87
Changed by : jirisuch on: 14.03.2014 at: 18:09:25

CALCULATION OF A HELICAL GEAR PAIR

Drawing or article number:
Gear 1: 0.000.0
Gear 2: 0.000.0

Calculation method DIN 3990:1987 Method B

		----- GEAR 1 -----	----- GEAR 2 -----
Power (kW)	[P]	510.246	
Speed (1/min)	[n]	854.4	1073.0
Torque (Nm)	[T]	5702.7	4541.0
Application factor	[KA]		1.20
Required service life	[H]		20000.00
Gear driving (+) / driven (-)		+	-

1. TOOTH GEOMETRY AND MATERIAL

(geometry calculation according to
ISO 21771:2007)

		----- GEAR 1 -----	----- GEAR 2 -----
Center distance (mm)	[a]	315.000	
Centre distance tolerance		ISO 286:2010 Measure H7	
Normal module (mm)	[mn]	6.0000	
Pressure angle at normal section (°)	[alfn]	20.0000	
Helix angle at reference circle (°)	[beta]	25.0000	
Number of teeth	[z]	54	43
Double helical gearing		right/left	left/right
Total facewidth of Gear (mm)	[b]	210.00	210.00
Width of intermediate groove (mm)	[bNut]		70.00
Facewidth for calculation (mm)	[beH]	70.00	70.00
Accuracy grade	[Q-DIN 3961:1978]	6	6
Inner diameter (mm)	[di]	0.00	0.00
Inner diameter of gear rim (mm)	[dbi]	0.00	0.00

Material

Gear 1: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)
Gear 2: 42 CrMo 4 (2), Through hardened steel, flame/ind. hardened
ISO 6336-5 Figure 11/12 (MQ)

		----- GEAR 1 -----	----- GEAR 2 -----
Surface hardness		HRC 56	HRC 56
Fatigue strength, tooth root stress (N/mm ²)	[sigFlim]	370.00	370.00
Fatigue strength for Hertzian pressure (N/mm ²)	[sigHlim]	1220.00	1220.00
Tensile strength (N/mm ²)	[Rm]	1100.00	1100.00
Yield point (N/mm ²)	[Rp]	900.00	900.00
Young's modulus (N/mm ²)	[E]	206000	206000
Poisson's ratio	[ny]	0.300	0.300
Mean roughness, Ra, tooth flank (µm)	[RAH]	0.60	0.60
Mean roughness height, Rz, flank (µm)	[RZH]	4.80	4.80
Mean roughness height, Rz, root (µm)	[RZF]	20.00	20.00

Tool or reference profile of gear 1 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C
Dedendum coefficient [hfP*] 1.250
Root radius factor [rhofP*] 0.250
Addendum coefficient [haP*] 1.000
Tip radius factor [rhoaP*] 0.000
Tip form height coefficient [hFaP*] 0.000
Protuberance height factor [hprP*] 0.000
Protuberance angle [alfprP] 0.000
Ramp angle [alfKP] 0.000

not topping

Tool or reference profile of gear 2 :

Reference profile 1.25 / 0.25 / 1.0 ISO 53.2:1997 Profil C

Dedendum coefficient	[hfP*]	1.250
Root radius factor	[rhofP*]	0.250
Addendum coefficient	[haP*]	1.000
Tip radius factor	[rhoaP*]	0.000
Tip form height coefficient	[hFaP*]	0.000
Protuberance height factor	[hprP*]	0.000
Protuberance angle	[alfprP]	0.000
Ramp angle	[alfKP]	0.000

not topping

Summary of reference profile gears:

Dedendum reference profile (module)	[hfP*]	1.250	1.250
Tooth root radius Refer. profile (module)	[rofP*]	0.250	0.250
Addendum Reference profile (module)	[haP*]	1.000	1.000
Protuberance height factor (module)	[hprP*]	0.000	0.000
Protuberance angle (°)	[alfprP]	0.000	0.000
Tip form height coefficient (module)	[hFaP*]	0.000	0.000
Ramp angle (°)	[alfKP]	0.000	0.000

Type of profile modification:

Tip relief (µm)	none (only running-in) [Ca]	3.4	3.4
-----------------	--------------------------------	-----	-----

Lubrication type	oil injection lubrication	
Type of oil	Oil: ISO-VG 46	
Lubricant base	Mineral-oil base	
Kinem. viscosity oil at 40 °C (mm²/s)	[nu40]	46.00
Kinem. viscosity oil at 100 °C (mm²/s)	[nu100]	6.70
FZG test A/8.3/90 (ISO 14635-1:2006)	[FZGtestA]	12
Specific density at 15 °C (kg/dm³)	[roOil]	0.880
Oil temperature (°C)	[TS]	70.000

----- GEAR 1 ----- GEAR 2 --

Overall transmission ratio	[itot]	-0.796	
Gear ratio	[u]	1.256	
Transverse module (mm)	[mt]	6.620	
Pressure angle at pitch circle (°)	[alft]	21.880	
Working transverse pressure angle (°)	[alfwt]	18.935	
	[alfwt.e/i]	18.963 / 18.935	
Working pressure angle at normal section (°)	[alfwn]	17.326	
Helix angle at operating pitch circle (°)	[betaw]	24.583	
Base helix angle (°)	[betab]	23.399	
Reference centre distance (mm)	[ad]	321.083	
Sum of profile shift coefficients	[Summexi]	-0.9504	
Profile shift coefficient	[x]	-0.5834	-0.3670
Tooth thickness (Arc) (module)	[sn*]	1.1461	1.3036
Tip alteration (mm)	[k*mn]	-0.380	-0.380
Reference diameter (mm)	[d]	357.494	284.672
Base diameter (mm)	[db]	331.742	264.165
Tip diameter (mm)	[da]	361.733	291.507
	[da.e/i]	361.733 / 361.503	291.507 / 291.497
Tip diameter allowances (mm)	[Ada.e/i]	0.000 / -0.230	0.000 / -0.010
Tip chamfer / tip rounding (mm)	[hK]	0.000	0.000
Tip form diameter (mm)	[dFa]	361.733	291.507
	[dFa.e/i]	361.733 / 361.503	291.507 / 291.497
Active tip diameter (mm)	[dNa.e/i]	361.733 / 361.503	291.507 / 291.497
Operating pitch diameter (mm)	[dw]	350.722	279.278
	[dw.e/i]	350.780 / 350.722	279.324 / 279.278
Root diameter (mm)	[df]	335.493	265.267
Generating Profile shift coefficient	[xE.e/i]	-0.6132 / -0.6269	-0.3968 / -0.4105
Manufactured root diameter with xE (mm)	[df.e/i]	335.136 / 334.971	264.910 / 264.745
Theoretical tip clearance (mm)	[c]	1.500	1.500
Effective tip clearance (mm)	[c.e/i]	1.928 / 1.678	1.818 / 1.678
Active root diameter (mm)	[dNf]	341.530	270.943
	[dNf.e/i]	341.611 / 341.530	271.144 / 270.943
Root form diameter (mm)	[dFf]	341.132	270.743
	[dFf.e/i]	340.910 / 340.808	270.534 / 270.439
Reserve (dNf-dFf)/2 (mm)	[cF.e/i]	0.402 / 0.310	0.352 / 0.204
Addendum (mm)	[ha = mn * (haP*+x)]	2.119	3.418
	[ha.e/i]	2.119 / 2.004	3.418 / 3.413
Dedendum (mm)	[hf = mn * (hfP*-x)]	11.001	9.702
	[hf.e/i]	11.179 / 11.262	9.881 / 9.963
Roll angle at dFa (°)	[xsi_dFa.e/i]	24.908 / 24.808	26.735 / 26.729
Roll angle to dNa (°)	[xsi_dNa.e/i]	24.908 / 24.808	26.735 / 26.729
Roll angle to dNf (°)	[xsi_dNf.e/i]	14.079 / 14.020	13.256 / 13.062
Roll angle at dFf (°)	[xsi_dFf.e/i]	13.563 / 13.486	12.657 / 12.562
Tooth height (mm)	[H]	13.120	13.120
Virtual gear no. of teeth	[zn]	70.739	56.329
Normal tooth thickness at tip cyl. (mm)	[san]	5.330	5.262

	(mm)	[san.e/i]	5.287 / 5.138	5.133 / 5.068
Normal spacewidth at root cylinder	(mm)	[efn]	5.645	5.664
	(mm)	[efn.e/i]	5.715 / 5.748	5.753 / 5.796
Max. sliding velocity at tip	(m/s)	[vga]	3.068	3.293
Specific sliding at the tip		[zetaaa]	0.476	0.476
Specific sliding at the root		[zetaf]	-0.907	-0.907
Sliding factor on tip		[Kga]	0.196	0.210
Sliding factor on root		[Kgf]	-0.210	-0.196
Pitch on reference circle	(mm)	[pt]		20.798
Base pitch	(mm)	[pbt]		19.300
Transverse pitch on contact-path	(mm)	[pet]		19.300
Lead height	(mm)	[pz]	2408.500	1917.880
Axial pitch	(mm)	[px]		44.602
Length of path of contact	(mm)	[ga, e/i]	31.520	(31.520 / 31.059)
Length T1-A, T2-A	(mm)	[T1A, T2A]	40.588(40.588/40.760)	61.631(61.631/61.619)
Length T1-B	(mm)	[T1B, T2B]	52.808(52.808/52.519)	49.411(49.411/49.860)
Length T1-C	(mm)	[T1C, T2C]	56.905(56.905/56.994)	45.313(45.313/45.384)
Length T1-D	(mm)	[T1D, T2D]	59.888(59.888/60.060)	42.331(42.331/42.319)
Length T1-E	(mm)	[T1E, T2E]	72.108(72.108/71.819)	30.111(30.111/30.560)
Length T1-T2	(mm)	[T1T2]	102.218	(102.218 / 102.378)
Diameter of single contact point B	(mm)			
		[d-B]	348.149(348.149/347.974)	282.044(282.044/282.360)
Diameter of single contact point D	(mm)			
		[d-D]	352.703(352.703/352.820)	277.400(277.400/277.393)
Addendum contact ratio		[eps]	0.788(0.788/ 0.768)	0.845(0.845/ 0.841)
Minimal length of contact line	(mm)	[Lmin]		116.888
Transverse contact ratio		[eps_a]		1.633
Transverse contact ratio with allowances		[eps_a.e/m/i]	1.633 / 1.621 / 1.609	
Overlap ratio		[eps_b-beH (eps_b-b)]		1.569 (3.139)
Total contact ratio		[eps_g]		3.203 (4.772)
Total contact ratio with allowances		[eps_g.e/m/i]	3.203/3.191/3.179	(4.772/4.760/4.748)

2. FACTORS OF GENERAL INFLUENCE

	----- GEAR 1 -----	GEAR 2 --
Nominal circum. force at pitch circle (N)		
	[Ft]	31903.4
Axial force (N)	[Fa]	0.0
Radial force (N)	[Fr]	12812.3
Normal force (N)	[Fnorm]	37460.7
Tangent.load at p.c.d.per mm (N/mm) (N/mm)		
	[w]	227.88
Only as information: Forces at operating pitch circle:		
Nominal circumferential force (N)	[Ftw]	32519.5
Axial force (N)	[Faw]	0.0
Radial force (N)	[Frw]	11156.4
Circumferential speed pitch d.. (m/sec)	[v]	15.99
Running-in value (µm)	[yp]	0.8
Running-in value (µm)	[yf]	0.8
Correction coefficient	[CM]	0.800
Gear body coefficient	[CR]	1.000
Reference profile coefficient	[CBS]	0.975
Material coefficient	[E/Est]	1.000
Singular tooth stiffness (N/mm/µm)	[c']	11.555
Meshing stiffness (N/mm/µm)	[cg]	17.042
Reduced mass (kg/mm)	[mRed]	0.16124
Resonance speed (min-1)	[nE1]	1818
Nominal speed (-)	[N]	0.470
Subcritical range		
Running-in value (µm)	[ya]	0.8
Bearing distance l of pinion shaft (mm)	[l]	336.000
Distance s of pinion shaft (mm)	[s]	16.800
Outside diameter of pinion shaft (mm)	[dsh]	168.000
Load according to figure 6.8, DIN 3990-1:1987	[-]	4
(0:6.8a, 1:6.8b, 2:6.8c, 3:6.8d, 4:6.8e)		
Coefficient K' according figure 6.8, DIN 3990-1:1987	[K']	-1.00
Without support effect		
Tooth trace deviation (active) (µm)	[Fby]	5.52
from deformation of shaft (µm)	[fsh*B1]	0.79
Tooth without tooth trace modification		
Position of Contact pattern: favorable		
from production tolerances (µm)	[fma*B2]	10.00
Tooth trace deviation, theoretical (µm)	[Fbx]	6.49
Running-in value (µm)	[yb]	1.0
Dynamic factor	[KV]	1.122

Face load factor - flank	[KHb]		1.153
- Tooth root	[KFb]		1.123
- Scuffing	[KBb]		1.153
Transverse load factor - flank	[KH _a]		1.109
- Tooth root	[KF _a]		1.109
- Scuffing	[KB _a]		1.109
Helical load factor scuffing	[K _{bg}]		1.294
Number of load cycles (in mio.)	[NL]	1025.311	1287.600

3. TOOTH ROOT STRENGTH

Calculation of Tooth form coefficients according method: B
(Calculate tooth shape coefficient YF with addendum mod. x)

		----- GEAR 1 -----	GEAR 2 --
Tooth form factor	[YF]	1.23	1.17
Stress correction factor	[YS]	2.01	2.11
Working angle (°)	[alfFen]	16.01	16.04
Bending lever arm (mm)	[hF]	5.22	5.00
Tooth thickness at root (mm)	[sFn]	12.51	12.56
Tooth root radius (mm)	[roF]	3.37	3.15
(hF* = 0.869/0.833 sFn* = 2.086/2.093 roF* = 0.562/0.525 dsFn = 337.80/267.46 alfsFn = 30.00/30.00)			
Contact ratio factor	[Yeps]		1.000
Helical load factor	[Ybet]		0.792
Effective facewidth (mm)	[beff]	70.00	70.00
Nominal shear stress at tooth root (N/mm ²)			
	[sigF0]	74.13	74.09
Tooth root stress (N/mm ²)	[sigF]	124.35	124.28
Permissible bending stress at root of Test-gear			
Notch sensitivity factor	[YdrelT]	0.994	0.995
Surface factor	[YRrelT]	0.957	0.957
Size coefficient (Tooth root)	[YX]	0.990	0.990
Finite life factor	[YNT]	1.000	1.000
	[YdrelT*YRrelT*YX*YNT]	0.941	0.942
Alternating bending coefficient	[YM]	1.000	1.000
Stress correction factor	[Yst]		2.00
Limit strength tooth root (N/mm ²)	[sigFG]	696.38	697.40
Permissible tooth root stress (N/mm ²)			
	[sigFP=sigFG/SFmin]	497.42	498.14
Required safety	[SFmin]	1.40	1.40
Safety for Tooth root stress	[SF=sigFG/sigF]	5.60	5.61
Transmittable power (kW)	[kWRating]	2041.12	2045.11

4. SAFETY AGAINST PITTING (TOOTH FLANK)

		----- GEAR 1 -----	GEAR 2 --
Zone factor	[ZH]		2.493
Elasticity coefficient (N ^{0.5} /mm)	[ZE]		189.812
Contact ratio factor	[Zeps]		0.783
Helix angle factor	[Zbet]		0.952
Effective facewidth (mm)	[beff]		70.00
Nominal flank pressure (N/mm ²)	[sigH0]		422.65
Surface pressure at operating pitch circle (N/mm ²)			
	[sigHw]		554.66
Single tooth contact factor	[ZB, ZD]	1.00	1.00
Flank pressure (N/mm ²)	[sigH]	554.66	554.66
Lubrication factor	[ZL]	0.931	0.931
Speed factor	[ZV]	1.014	1.014
Roughness factor	[ZR]	0.993	0.993
Material mating factor	[ZW]	1.000	1.000
Finite life factor	[ZNT]	1.000	1.000
	[ZL*ZV*ZR*ZNT]	0.937	0.937
Small amount of pitting permissible (0=no, 1=yes)		0	0
Size coefficient (flank)	[ZX]	1.000	1.000
Limit strength pitting (N/mm ²)	[sigHG]	1143.62	1143.62
Permissible surface pressure (N/mm ²) [sigHP=sigHG/SHmin]		1143.62	1143.62
Safety for surface pressure at operating pitch circle			
	[SHw]	2.06	2.06
Required safety	[SHmin]	1.00	1.00
Transmittable power (kW)	[kWRating]	2169.16	2169.16
Safety for stress at single tooth contact			
	[SHBD=sigHG/sigH]	2.06	2.06
(Safety regarding nominal torque)	[(SHBD)^2]	4.25	4.25

4b. MICROPITTING ACCORDING TO ISO TR 15144-1:2010

Calculation did not run. (Lubricant: Load stage micropitting test is unknown)

5. STRENGTH AGAINST SCUFFING

Calculation method according to
DIN 3990:1987

Lubrication coefficient (for lubrication type)	[XS]	1.200	
Relative structure coefficient (Scuffing)	[XWrelT]	1.000	
Thermal contact factor (N/mm/s ^{0.5} /K)	[BM]	13.780	13.780
Relevant tip relief (µm)	[Ca]	3.40	3.40
Optimal tip relief (µm)	[Ceff]	10.70	
Effective facewidth (mm)	[beff]	70.000	
Applicable circumferential force/facewidth (N/mm)	[wBt]	507.875	
Pressure angle factor (eps1: 0.788, eps2: 0.845)	[Xalfbet]	0.944	
Flash temperature-criteria			
Tooth mass temperature (°C)	[theM-B]	86.26	
theM-B = theoil + XS*0.47*theflamax	[theflamax]	28.83	
Scuffing temperature (°C)	[theS]	469.40	
Coordinate gamma (point of highest temp.)	[Gamma]	-0.335	
[Gamma.A]= -0.287 [Gamma.E]= 0.267			
Highest contact temp. (°C)	[theB]	115.10	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Geometry factor	[XB]	0.235	
Load sharing factor	[XGam]	0.333	
Dynamic viscosity (mPa*s)	[etaM]	7.81	
Coefficient of friction	[mym]	0.077	
Required safety	[SBmin]	2.000	
Safety factor for scuffing (flash-temp)	[SB]	8.855	
Integral temperature-criteria			
Tooth mass temperature (°C)	[theM-C]	85.11	
theM-C = theoil + XS*0.70*theflaint	[theflaint]	17.99	
Integral scuffing temperature (°C)	[theSint]	469.40	
Flash factor (°K*N ^{-0.75} *s ^{0.5} *m ^{-0.5} mm)	[XM]	50.058	
Contact ratio factor	[Xeps]	0.252	
Dynamic viscosity (mPa*s)	[etaOil]	12.31	
Averaged coefficient of friction	[mym]	0.065	
Geometry factor	[XBE]	0.235	
Meshing factor	[XQ]	1.000	
Tip relief factor	[XCa]	1.027	
Integral tooth flank temperature (°C)	[theint]	112.09	
Required safety	[SSmin]	1.800	
Safety factor for scuffing (intg.-temp.)	[SSint]	4.188	
Safety referring to transferred torque	[SSL]	9.489	

6. MEASUREMENTS FOR TOOTH THICKNESS

		----- GEAR 1 -----	----- GEAR 2 -----
		DIN 3967:1978 cd25	DIN 3967:1978 cd25
Tooth thickness deviation			
Tooth thickness allowance (normal section) (mm)	[As.e/i]	-0.130 / -0.190	-0.130 / -0.190
Number of teeth spanned	[k]	7.000	6.000
Base tangent length (no backlash) (mm)	[Wk]	118.741	100.694
Actual base tangent length ('span') (mm)	[Wk.e/i]	118.619 / 118.562	100.571 / 100.515
Diameter of contact point (mm)	[dMWk.m]	349.140	279.818
Theoretical diameter of ball/pin (mm)	[DM]	9.951	9.953
Eff. Diameter of ball/pin (mm)	[DMeff]	10.000	10.000
Theor. dim. centre to ball (mm)	[MrK]	181.854	146.799
Actual dimension centre to ball (mm)	[MrK.e/i]	181.662 / 181.572	146.615 / 146.530
Diameter of contact point (mm)	[dMMr.m]	350.187	279.973
Diametral measurement over two balls without clearance (mm)	[MdK]	363.708	293.409
Actual dimension over balls (mm)	[MdK.e/i]	363.323 / 363.144	293.042 / 292.871
Diametral measurement over rolls without clearance (mm)	[MdR]	363.708	293.598
Actual dimension over rolls (mm)	[MdR.e/i]	363.323 / 363.144	293.231 / 293.060
Dimensions over 3 rolls without clearance (mm)			

	[Md3R]	0.000	293.598
Actual dimensions over 3 rolls (mm)	[Md3R.e/i]	0.000 / 0.000	293.231 / 293.060
Chordal tooth thickness (no backlash) (mm)			
	['sn]	6.876	7.821
Actual chordal tooth thickness (mm)	['sn.e/i]	6.746 / 6.686	7.691 / 7.631
Reference chordal height from da.m (mm)	[ha]	2.089	3.460
Tooth thickness (Arc) (mm)	[sn]	6.877	7.822
	(mm) [sn.e/i]	6.747 / 6.687	7.692 / 7.632
Backlash free center distance (mm) [aControl.e/i]			
		314.588	/314.396
Backlash free center distance, allowances (mm)			
	[jta]	-0.412	/ -0.604
Centre distance allowances (mm)	[Aa.e/i]	0.052	/ 0.000
Circumferential backlash from Aa (mm)	[jt_Aa.e/i]	0.036	/ 0.000
Radial clearance (mm)	[jr]	0.656	/ 0.412
Circumferential backlash (transverse section) (mm)			
	[jt]	0.447	/ 0.281
Torsional angle for fixed gear 1 (°)		0.1799	/0.1133
Normal backlash (mm)	[jn]	0.381	/ 0.240

7. GEAR ACCURACY

		----- GEAR 1 -----	GEAR 2 --
According to			
DIN 3961:1978:			
Accuracy grade	[Q-DIN3961]	6	6
Profile form deviation (µm)	[ff]	10.00	10.00
Profile slope deviation (µm)	[fHa]	7.00	7.00
Total profile deviation (µm)	[Ff]	13.00	13.00
Helix form deviation (µm)	[ffb]	8.00	8.00
Helix slope deviation (µm)	[fHb]	10.00	10.00
Total helix deviation (µm)	[Fb]	13.00	13.00
Normal base pitch deviation (µm)	[fpe]	10.00	10.00
Single pitch deviation (µm)	[fp]	10.00	10.00
Difference between adjacent pitches (µm)	[fu]	12.00	12.00
Total cumulative pitch deviation (µm)	[Fp]	40.00	40.00
Cumulative circular pitch deviation over z/8 pitches (µm)			
	[Fpz/8]	25.00	25.00
Concentricity deviation (µm)	[Fr]	28.00	28.00
Tooth Thickness Variation (µm)	[Rs]	16.00	16.00
Total radial composite deviation (µm)	[Fi"]	32.00	32.00
Radial tooth-to-tooth composite deviation (µm)			
	[fi"]	14.00	14.00
Total tangential composite deviation (µm)			
	[Fi']	42.00	42.00
Tangential tooth-to-tooth composite deviation (µm)			
	[fi']	16.00	16.00
Axis alignment tolerances (recommendation acc. ISO TR 10064:1992, Quality 6)			
Maximum value for deviation error of axis (µm)	[fSigbet]	36.00	(Fb=15.00)
Maximum value for inclination error of axes (µm)	[fSigdel]	72.00	

8. ADDITIONAL DATA

Torsional stiffness (MNm/rad)	[cr]	65.6	41.6
Mean coeff. of friction (acc. Niemann)	[mum]	0.033	
Wear sliding coef. by Niemann	[zetw]	0.777	
Power loss from gear load (kW)	[PVZ]	1.666	
(Meshing efficiency (%))	[etaz]	99.673)	
Weight - calculated with da (kg)	[Mass]	168.985	109.741
Total weight (kg)	[Mass]	278.726	
Moment of inertia (System referenced to wheel 1):			
calculation without consideration of the exact tooth shape			
single gears ((da+df)/2...di) (kg*m²)	[TraeghMom]	2.37670	0.96648
System ((da+df)/2...di) (kg*m²)	[TraeghMom]	3.90090	

9. DETERMINATION OF TOOTHFORM

Data for the tooth form calculation :
Data not available.

REMARKS:

- Specifications with [.e/i] imply: Maximum [e] and Minimal value [i] with

consideration of all tolerances
Specifications with [.m] imply: Mean value within tolerance
- For the backlash tolerance, the center distance tolerances and the tooth thickness deviation are taken into account. Shown is the maximal and the minimal backlash corresponding the largest resp. the smallest allowances
The calculation is done for the Operating pitch circle..
- Details of calculation method:
cg according to method B
KV according to method B
KHb, KFb according method C
KHa, KFa according to method B

End report

lines: 501

Příloha 2: hydrodynamická ložiska WAUKESHA

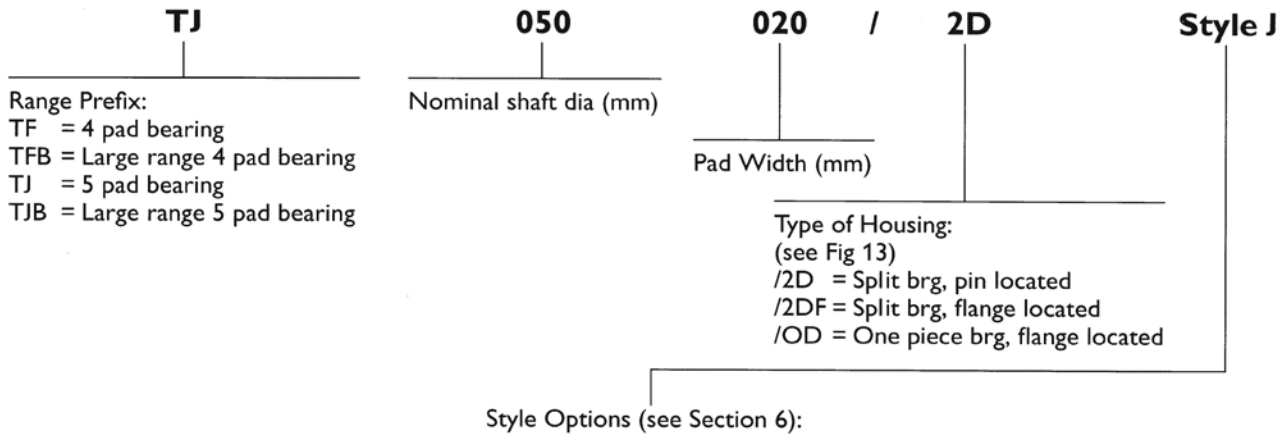
SIZE CODES

Waukesha Tilting Pad Radial Bearings are identified by a two part code which consists of the bearing size followed by a suffix indicating the type of construction.

The size designation is shown in the left-hand column of the Size Tables on Pg. 19 while the suffix options are shown below.

In addition to the basic two part code, various additional features can be specified by referencing an appropriate Style option from Pg. 11. Note than in many cases the use of the Style designation does not completely describe the feature required and additional information is required.

Code Nomenclature



AP = Adjustable pivots	IT1 = Provision for customer supply temperature sensors	OP = Offset pivot pads
AR60 = 60° arc pads on Series TF Bearings	IT2 = Temperatures sensors (Waukesha supply)	TLG or TLG2 = Single or double plain grooved axial face
BP = Two pad orientation	IR = Provision for customer supply proximity probes	TLU or TLU2 = Single or double taper land axial face (uni-directional)
CL = Curved line pivot	J = Hydrostatic jacking	TLB or TLB2 = Single or double taper land axial face (bi-directional)
FL or FL2 = Single or double floating seal	KN or KN2 = Single or double knife edge end plate	TP or TP2 = Single or double tilting pad axial face

Examples of complete bearing reference codes which should be used for orders or enquiries are as follows:

Code	Description
TJ050-020/2D	50mm 5 pad bearing, b/d = 0.4, split, pin located
TJ100-100/OD	100mm 5 pad bearing, b/d = 1.0, one piece, flange located
TF120-084/2DF Style J	120mm 4 pad bearing, b/d = 0.7, split, flange located with jacking
TJ200-080/2DF Style BP, FL, IR	200mm 5 pad bearing, b/d = 0.4, split, flange located with two pad orientation, single floating seal and provision for radial proximity probes
TJ250-250/2DF Style TP2	250mm 5 pad bearing, b/d = 1.0, split, flange located with tilting pad axial faces on both ends

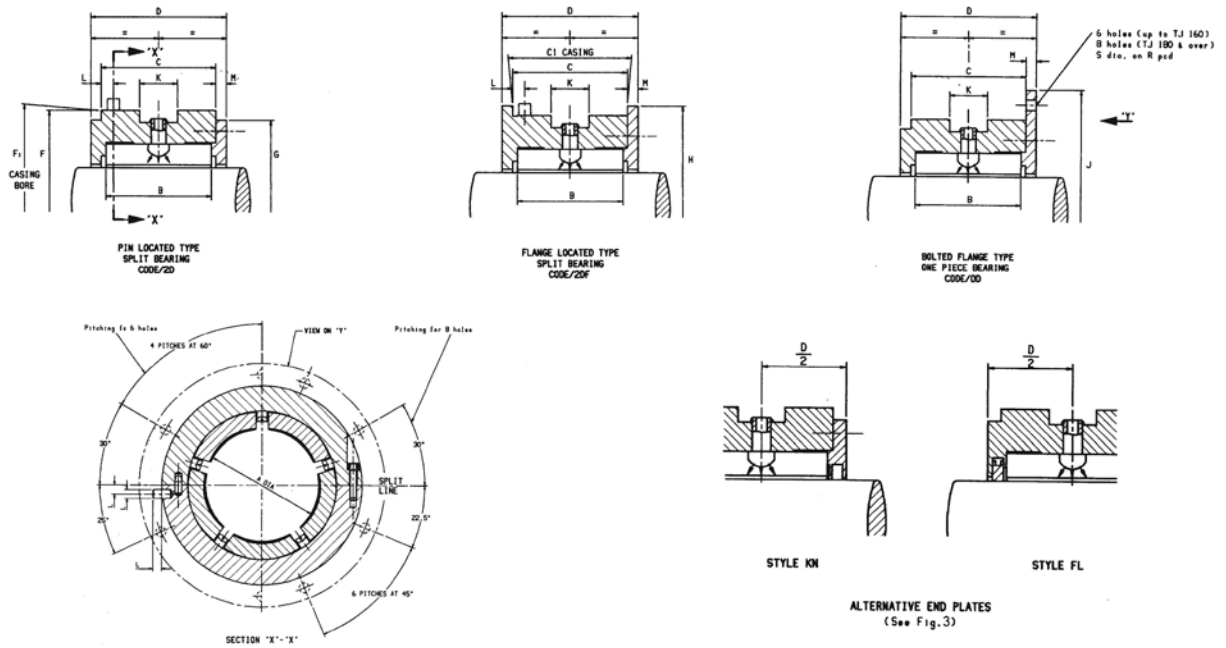


Table 1

b/d = 0.4 Size	Nom Shaft Dia A	Pad Width B	C	Recom- mended Casing C1	Width D	F	Recom- mended Casing Bore F1 Dia*	G Dia	H Dia	J Dia	K	L	M	R PC Dia	S Dia	Maximum Load (N) See Section 3		Weight (kg)
																Load on pad	Load between pads	
TF TJ 020-008	20	8	13	12.994 12.976	21	58	58.019 58.000	54	65	86	6	4	4	72	5.5	335	445	0.3
TF TJ 025-010	25	10	15	14.994 14.976	23	62	62.019 62.000	60	69	90	6	4	4	76	5.5	520	700	0.4
TF TJ 030-012	30	12	17	16.994 16.976	25	69	69.019 69.000	66	76	97	6	4	4	83	5.5	750	1000	0.5
TF TJ 035-014	35	14	19	18.993 18.972	27	76	76.019 76.000	72	80	100	6	4	4	86	5.5	1025	1370	0.7
TF TJ 040-016	40	16	21	20.993 20.972	31	82	82.022 82.000	78	90	110	6	4	5	96	5.5	1340	1790	0.8
TF TJ 045-018	45	18	23	22.993 22.972	33	89	89.022 89.000	85	98	117	6	4	5	103	5.5	1700	2270	0.9
TF TJ 050-020	50	20	25	24.993 24.972	35	95	95.022 95.000	92	104	127	7.5	4	5	111	6.6	2100	2800	1
TF TJ 055-022	55	22	27	26.993 26.972	37	111	111.022 111.000	100	120	143	7.5	5	5	127	6.6	2540	3390	1.6
TF TJ 060-024	60	24	29	28.993 28.972	39	120	120.022 120.000	106	130	152	9	5	5	136	6.6	3020	4030	2
TF TJ 070-028	70	28	33	32.991 32.966	45	130	130.025 130.000	118	141	162	11	5	6	146	6.6	4120	5490	2.6
TF TJ 080-032	80	32	37	36.991 36.966	49	139	139.025 139.000	130	150	171	11	6	6	155	6.6	5400	7170	3
TF TJ 090-036	90	36	42	41.991 41.966	56	165	165.025 165.000	152	177	197	14	6	7	181	6.6	6800	9070	5
TF TJ 100-040	100	40	46	45.991 45.966	60	177	177.025 177.000	164	190	217	14	8	7	197	9	8400	11 200	6
TF TJ 110-044	110	44	50	49.991 49.966	68	190	190.029 190.000	176	204	230	16	8	9	210	9	10 200	13 600	8
TF TJ 120-048	120	48	54	53.990 53.960	72	215	215.029 215.000	188	230	255	17	10	9	235	9	12 100	16 100	11
TF TJ 140-056	140	56	63	62.990 62.960	83	228	228.029 228.000	212	244	268	21	10	10	248	9	16 500	22 000	13
TF TJ 160-064	160	64	71	70.990 70.960	95	266	266.032 266.000	245	284	314	22	12	12	290	11	21 500	28 700	20
TF TJ 180-072	180	72	80	79.990 79.960	104	298	298.032 298.000	278	317	354	25	12	12	326	14	27 200	36 300	27
TF TJ 200-080	200	80	88	87.988 87.953	114	336	336.036 336.000	302	357	392	28	16	13	364	14	33 600	44 800	38
TF TJ 220-088	220	88	96	95.988 95.953	128	374	374.036 374.000	326	397	430	31	16	16	402	14	40 700	54 200	53
TF TJ 250-100	250	100	109	108.988 108.953	145	406	406.040 406.000	371	431	478	35	20	18	442	18	52 500	70 000	65
TF TJ 280-112	280	112	122	121.986 121.946	160	450	450.040 450.000	407	477	522	39	20	19	486	18	65 900	87 800	86
TF TJ 300-120	300	120	130	129.986 129.946	172	482	482.040 482.000	431	511	554	42	20	21	518	18	75 600	101 000	110

*Gives H6-h6 fit for /2D and /2DF bearings and H6-g6 fit for /OD bearings

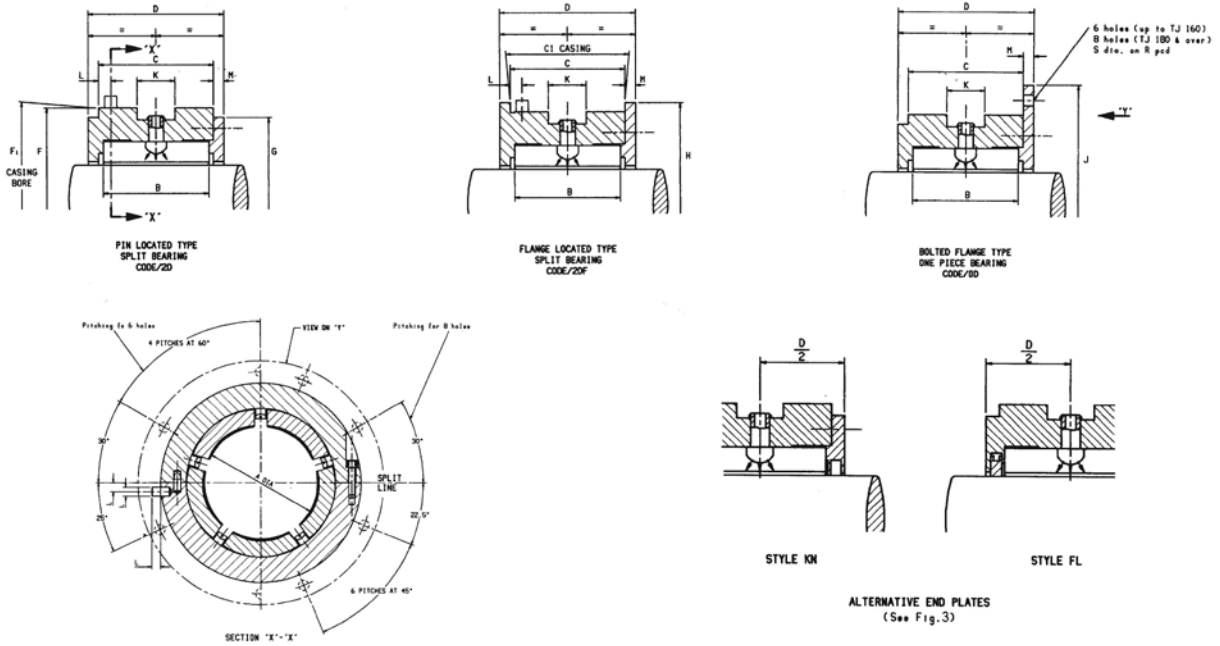


Table 2

b/d = 0.7 Size	Nom Shaft Dia A	Pad Width B	C	Recom- mended Casing C1	Width		Recom- mended Casing Bore F1 Dia*	G Dia	H Dia	J Dia	K	L	M	R	S	Maximum Load (N) See Section 3		Weight (kg)
					D	F										Load on pad	Load between pads	
TF TJ 020-014	20	14	19	18.993 18.972	27	58	58.019 58.000	54	65	86	6	4	4	72	5.5	590	785	0.4
TF TJ 025-017	25	17	22	21.993 21.972	30	62	62.019 62.000	60	69	90	6	4	4	76	5.5	920	1225	0.5
TF TJ 030-021	30	21	26	25.993 25.972	34	69	69.019 69.000	66	76	97	8	4	4	83	5.5	1320	1760	0.7
TF TJ 035-024	35	24	29	28.993 28.972	37	76	76.019 76.000	72	80	100	9	4	4	86	5.5	1800	2400	0.9
TF TJ 040-028	40	28	33	32.991 32.966	43	82	82.022 82.000	78	90	110	10	4	5	96	5.5	2350	3140	1.2
TF TJ 045-031	45	31	36	35.991 35.966	46	89	89.022 89.000	85	98	117	11	4	5	103	5.5	3020	4030	1.4
TF TJ 050-035	50	35	40	39.991 39.966	50	95	95.022 95.000	92	104	127	12	4	5	111	6.6	3670	4900	1.6
TF TJ 055-038	55	38	43	42.991 42.966	53	111	111.022 111.000	100	120	143	13	5	5	127	6.6	4500	5930	2.4
TF TJ 060-042	60	42	47	46.991 46.066	57	120	120.022 120.000	106	130	152	15	5	5	136	6.6	5290	7060	3.3
TF TJ 070-049	70	49	54	53.990 53.960	66	130	130.025 130.000	118	141	162	17	5	6	146	6.6	7200	9600	4
TF TJ 080-056	80	56	61	60.990 60.960	73	139	139.025 139.000	130	150	171	20	6	6	155	6.6	9410	12500	5
TF TJ 090-063	90	63	69	68.990 68.960	83	165	165.025 165.000	152	177	197	22	6	7	181	6.6	11900	15900	8
TF TJ 100-070	100	70	76	75.990 75.960	90	177	177.025 177.000	164	190	217	25	8	7	197	9	14700	19600	10
TF TJ 110-077	110	77	83	82.988 82.953	101	190	190.029 190.000	176	204	230	27	8	9	210	9	17800	23700	12
TF TJ 120-084	120	84	90	89.988 89.953	108	215	215.029 215.000	188	230	255	29	10	9	235	9	21200	28200	17
TF TJ 140-098	140	98	105	104.988 104.953	125	228	228.029 228.000	212	244	268	34	10	10	248	9	28800	38400	21
TF TJ 160-112	160	112	119	118.988 118.953	143	266	266.032 266.000	245	284	314	39	12	12	290	11	37600	50200	31
TF TJ 180-126	180	126	134	133.986 133.946	160	298	298.032 298.000	278	317	354	44	12	12	326	14	47600	63500	43
TF TJ 200-140	200	140	148	147.986 147.946	174	336	336.036 336.000	302	357	392	49	16	13	364	14	58800	78400	61
TF TJ 220-154	220	154	162	161.986 161.946	194	374	374.036 374.000	326	397	430	54	16	16	402	14	71100	94900	85
TF TJ 250-175	250	175	184	183.985 183.939	220	406	406.040 406.000	371	431	478	61	20	18	442	18	91900	122000	102
TF TJ 280-196	280	196	206	205.985 205.939	244	450	450.040 450.000	407	477	522	69	20	19	486	18	115000	154000	142
TF TJ 300-210	300	210	220	219.985 219.939	262	482	482.040 482.000	431	511	554	74	20	21	518	18	132000	176000	175

*Gives H6-h6 fit for /2D and /2DF bearings and H6-g6 fit for /OD bearings

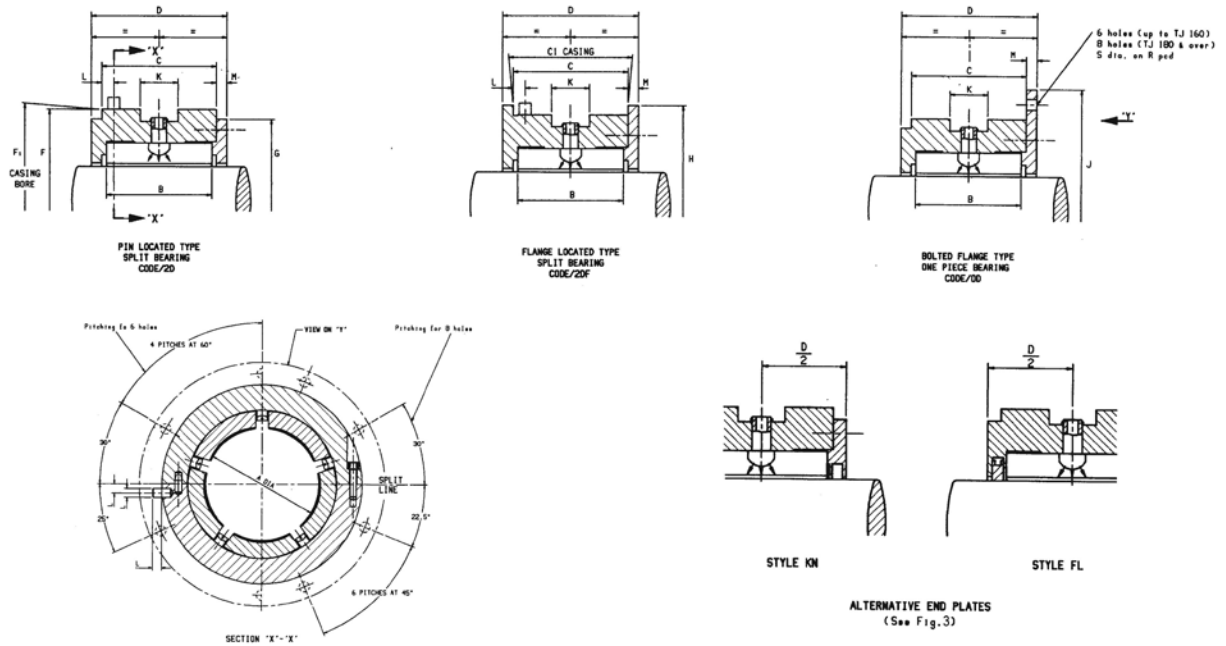
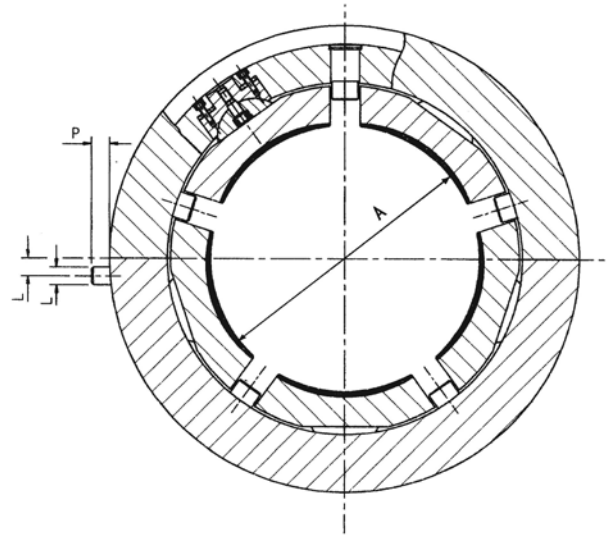
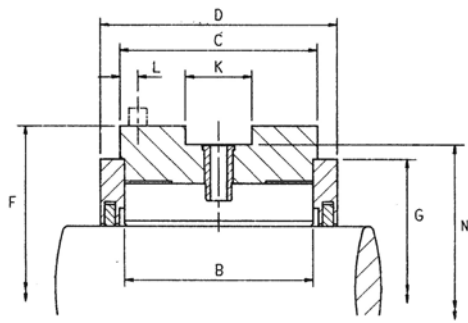


Table 3

b/d = 1.0 Size	Nom Shaft Dia A	Pad Width B	C	Recommended Casing C1	Width		Recommended Casing Bore F1 Dia*	G Dia	H Dia	J Dia	K	L	M	R PC Dia	S Dia	Maximum Load (N) See Section 3		Weight (kg)
					D	F										Load on pad	Load between pads	
TF TJ 020-020	20	20	25	24.993 24.972	33	58	58.019 58.000	54	65	86	7	4	4	72	5.5	840	1120	0.5
TF TJ 025-025	25	25	30	29.993 29.972	38	62	62.019 62.000	60	69	90	9	4	4	76	5.5	1310	1750	0.7
TF TJ 030-030	30	30	35	34.991 34.966	43	69	69.019 69.000	66	76	97	11	4	4	83	5.5	1890	2520	0.9
TF TJ 035-035	35	35	40	39.991 39.966	48	76	76.019 76.000	72	80	100	13	4	4	86	5.5	2570	3430	1.2
TF TJ 040-040	40	40	45	44.991 44.966	55	82	82.022 82.000	78	90	110	14	4	5	96	5.5	3360	4480	1.4
TF TJ 045-045	45	45	50	49.991 49.966	60	89	89.022 89.000	85	98	117	16	4	5	103	5.5	4250	5670	1.8
TF TJ 050-050	50	50	55	54.990 54.960	65	95	95.022 95.000	92	104	127	18	4	5	111	6.6	5250	7000	2.3
TF TJ 055-055	55	55	60	59.990 59.960	70	111	111.022 111.000	100	120	143	19	5	5	127	6.6	6350	8470	3.3
TF TJ 060-060	60	60	65	64.990 64.960	75	120	120.022 120.000	106	130	152	21	5	5	136	6.6	7560	10100	4.2
TF TJ 070-070	70	70	75	74.990 74.960	87	130	130.025 130.000	118	141	162	25	5	6	146	6.6	10300	13700	5
TF TJ 080-080	80	80	85	84.988 84.953	97	139	139.025 139.000	130	150	171	28	6	6	155	6.6	13400	17900	6
TF TJ 090-090	90	90	96	95.988 95.953	110	165	165.025 165.000	152	177	197	32	6	7	181	6.6	17000	22700	10
TF TJ 100-100	100	100	106	105.988 105.953	120	177	177.025 177.000	164	190	217	35	8	7	197	9	21000	28000	13
TF TJ 110-110	110	110	116	115.988 115.953	134	190	190.029 190.000	176	204	230	39	8	9	210	9	25400	33900	16
TF TJ 120-120	120	120	126	125.986 125.946	144	215	215.029 215.000	188	230	255	42	10	9	235	9	30200	40300	22
TF TJ 140-140	140	140	147	146.986 146.946	167	228	228.029 228.000	212	244	268	49	10	10	248	9	41200	54900	26
TF TJ 160-160	160	160	167	166.986 166.946	191	266	266.032 266.000	245	284	314	56	12	12	290	11	53800	71700	41
TF TJ 180-180	180	180	188	187.985 187.939	212	298	298.032 298.000	278	317	354	63	12	12	326	14	68000	90700	58
TF TJ 200-200	200	200	208	207.985 207.939	234	336	336.036 336.000	302	357	392	70	16	13	364	14	84000	112000	84
TF TJ 220-220	220	220	228	227.985 227.939	260	374	374.036 374.000	326	397	430	77	16	16	402	14	102000	136000	115
TF TJ 250-250	250	250	259	258.983 258.938	295	406	406.040 406.000	371	431	478	88	20	18	442	18	131000	175000	144
TF TJ 280-280	280	280	290	289.983 289.938	328	450	450.040 450.000	407	477	522	98	20	19	486	18	165000	220000	194
TF TJ 300-300	300	300	310	309.983 309.938	352	482	482.040 482.000	431	511	554	105	20	21	518	18	189000	252000	239

*Gives H6-h6 fit for /2D and /2DF bearings and H6-g6 fit for /OD bearings



NOTE: TJB SERIES BEARING IS SHOWN.
TFB SERIES BEARINGS HAVE
SAME EXTERNAL DIMENSION

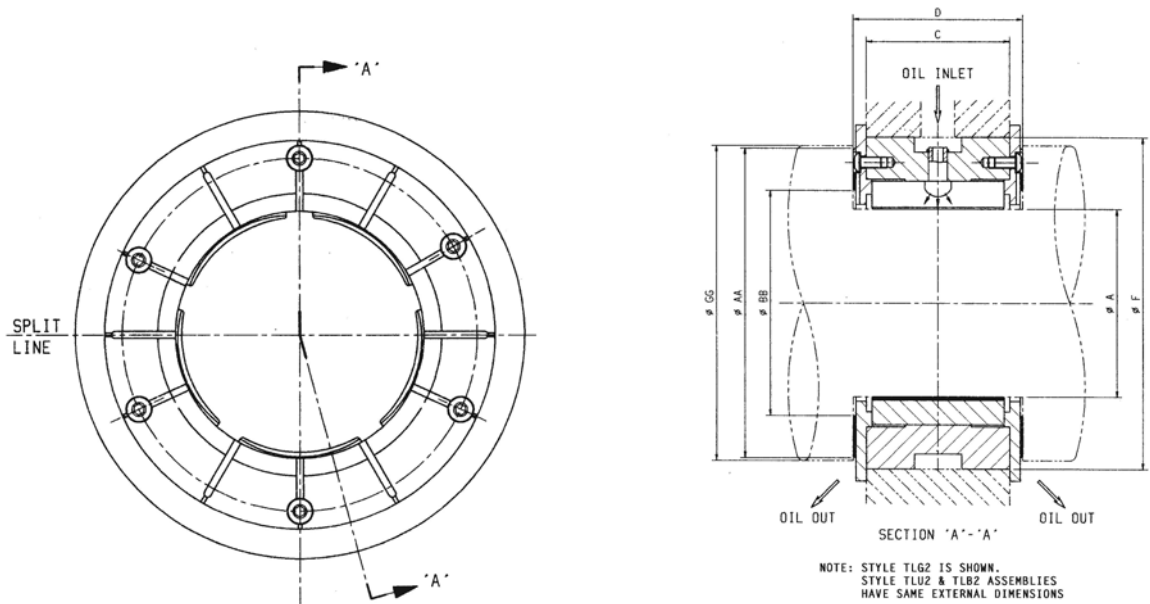
Table 4

b/d = 0.7		Nom. Shaft Diameter	Pad Width	C	Width D	F Dia	G Dia	K	L	N Dia	P
Size		A	B								
TJB	300-210	300	210	220	264	525	450	74	20	489	14
TFB											
TJB	350-245	350	245	256	304	593	512	86	25	551	18
TFB											
TJB	400-280	400	280	291	345	684	577	98	25	636	18
TFB											
TJB	450-315	450	315	327	385	752	640	110	30	698	21
TFB											
TJB	500-350	500	350	362	425	838	713	123	30	778	21
TFB											
TJB	550-385	550	385	398	467	904	776	135	35	838	25
TFB											
TJB	600-420	600	420	433	506	997	841	147	40	925	28
TFB											
TJB	650-455	650	455	469	546	1065	905	159	40	987	28
TFB											
TJB	700-490	700	490	504	586	1159	971	172	45	1075	32
TFB											
TJB	750-525	750	525	540	627	1225	1033	184	50	1135	35
TFB											

Orders & Enquiries

When enquiring for or ordering Waukesha Tilting Pad Radial Bearings from this Handbook, we recommend that the anticipated operating conditions are given so that confirmation can be given for the bearing selection. Please use the Data Sheet on Pg. 25 or state the following:

1. Application.
2. Shaft diameter – with tolerance if non-standard shaft to be used.
3. Shaft speed – normal and maximum.
4. Load – normal, maximum and at start-up, also angle and whether steady or rotating.
5. Oil grade to be used – also inlet temperature and pressure at entry to the bearing.
6. Optional features – If these are required, additional information may be needed as indicated in the appropriate Style description.



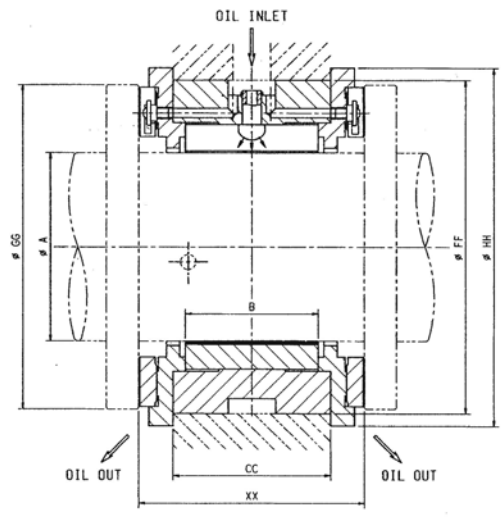
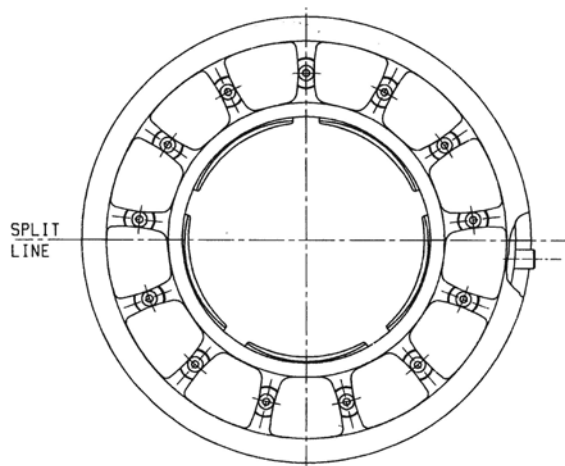
Sizes and Axial Load Capacity for Style TL

(for single letter dimensions see main dimension tables – Pgs. 21-23)

Tilting Pad Radial Brg Size	Axial Face O. Dia	Axial Face I. Dia	Axial Collar O. Dia	Nominal Load Capacity (N)		
				Plain Grooved Face	Taperland Face (See Note)	
					Unidirectional	Bidirectional
TF TJ 020	55	30	57	600	6100	3200
TF TJ 025	60	35	62	650	6800	3800
TF TJ 030	65	40	67	700	7300	4250
TF TJ 035	75	45	77	1000	10 100	5800
TF TJ 040	80	50	82	1100	10 500	6200
TF TJ 045	85	55	87	1200	11 000	6600
TF TJ 050	95	60	98	1500	14 500	8850
TF TJ 055	100	70	103	1400	12 400	7500
TF TJ 060	105	75	108	1500	12 700	7700
TF TJ 070	120	85	123	2000	16 600	10 200
TF TJ 080	130	95	133	2200	17 000	10 450
TF TJ 090	155	105	158	3500	33 300	20 000
TF TJ 100	165	120	168	3500	29 000	17 600
TF TJ 110	175	130	178	3800	29 300	17 800
TF TJ 120	190	140	193	4500	36 000	22 000
TF TJ 140	215	160	218	5700	43 000	26 200
TF TJ 160	245	185	248	7100	52 500	32 000
TF TJ 180	280	210	283	9400	71 500	43 900
TF TJ 200	305	230	309	11 000	80 000	49 000
TF TJ 220	325	250	329	11 900	80 000	49 000
TF TJ 250	370	285	374	15 300	102 500	62 200
TF TJ 280	410	320	415	18 000	113 000	69 000
TF TJ 300	430	340	435	19 000	113 000	69 200

NOTE Load capacities for taperland faces are for preliminary guidance only: they are based on the high speed dotted line in FIG 4(a) with the same oil conditions

Fig 11 Plain/taper land Axial Faces – Style TL (Assemblies with low/medium axial load capacity)



NOTE : STYLE TP2 IS SHOWN

Sizes and Axial Load Capacity for Style TP
 (for single letter dimensions see main dimension tables – Pgs. 21-23)

Tilting Pad Radial Size	Tilting Pad Axial Brg Size (see note)	Housing Width			Housing O. Dia	Collar O. Dia	Flange O. Dia	Axial Length			Maximum Load Capacity (N) (see note)
		b/d = 0.4	b/d = 0.7	b/d = 1.0				b/d = 0.4	b/d = 0.7	b/d = 1.0	
		CC	FF	GG				HH	XX		
TF TJ 040	M1347	26	33	55	82	79	90	48	55	67	3980
TF TJ 045	M1256	28	36	50	89	88	98	51	59	73	5860
TF TJ 050	M1356	31	40	55	95	94	104	54	63	78	6350
TF TJ 055	M1456	35	43	60	111	100	120	58	66	83	6816
TF TJ 060	M1367	35	47	65	120	113	130	61	73	91	9910
TF TJ 070	M1379	39	54	75	134	133	145	68	83	104	15 280
TF TJ 080	M1479	46	61	85	146	141	157	75	90	114	16 530
TF TJ 090	M1394	50	69	96	165	158	177	82	101	128	24 220
TF TJ 100	M13103	53	76	106	177	172	190	89	112	142	29 450
TF TJ 110	M13112	59	83	116	190	188	204	97	121	154	35 860
TF TJ 120	M13123	62	90	126	215	204	230	105	133	169	43 390
TF TJ 140	M13146	71	105	147	240	243	256	118	152	194	64 100
TF TF 160	M14146	85	119	167	266	260	284	132	166	214	69 120
TF TJ 180	M12190	88	134	188	298	294	317	146	192	246	102 560
TF TJ 200	M14190	102	148	208	336	335	357	160	220	280	120 250
TF TJ 220	M14207	108	162	228	374	365	397	174	228	294	143 190
TF TJ 250	M14225	127	202	277	406	400	431	196	253	328	172 550
TF TJ 280	M13269	138	206	290	450	448	477	217	285	369	229 640
TF TJ 300	M14269	152	220	310	482	476	511	231	299	389	247 000

NOTE Tilting pad axial bearings are from the MS range as described in Designer's Handbook 5A: see bearing selection comments for restrictions in use of maximum load capacity.

Fig 12 Tilting Pad Axial Faces – Style TP (Assemblies with high axial load capacity)

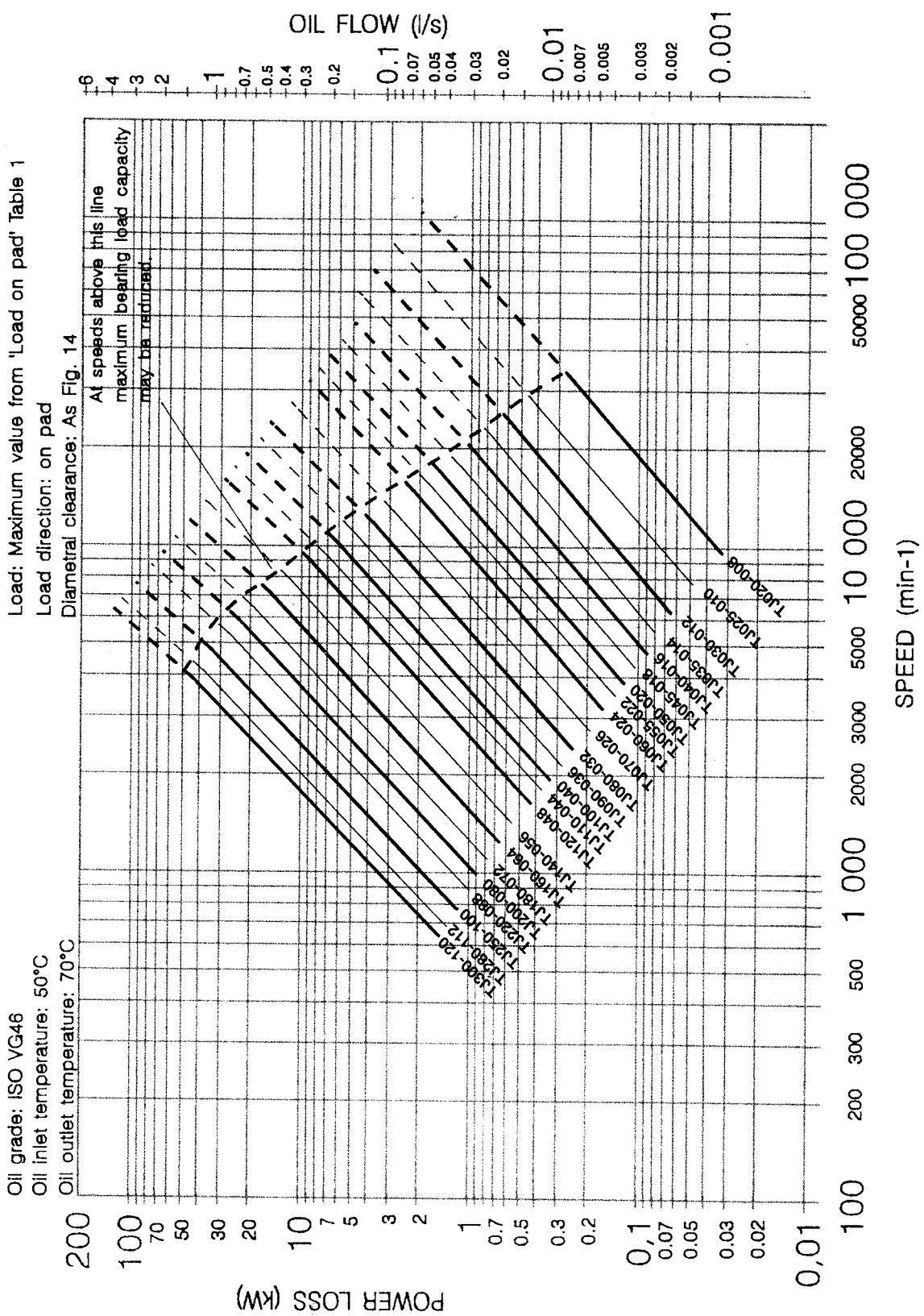


Fig 4(a) Power loss and Oil Flow. TJ series. B/D = 0.4

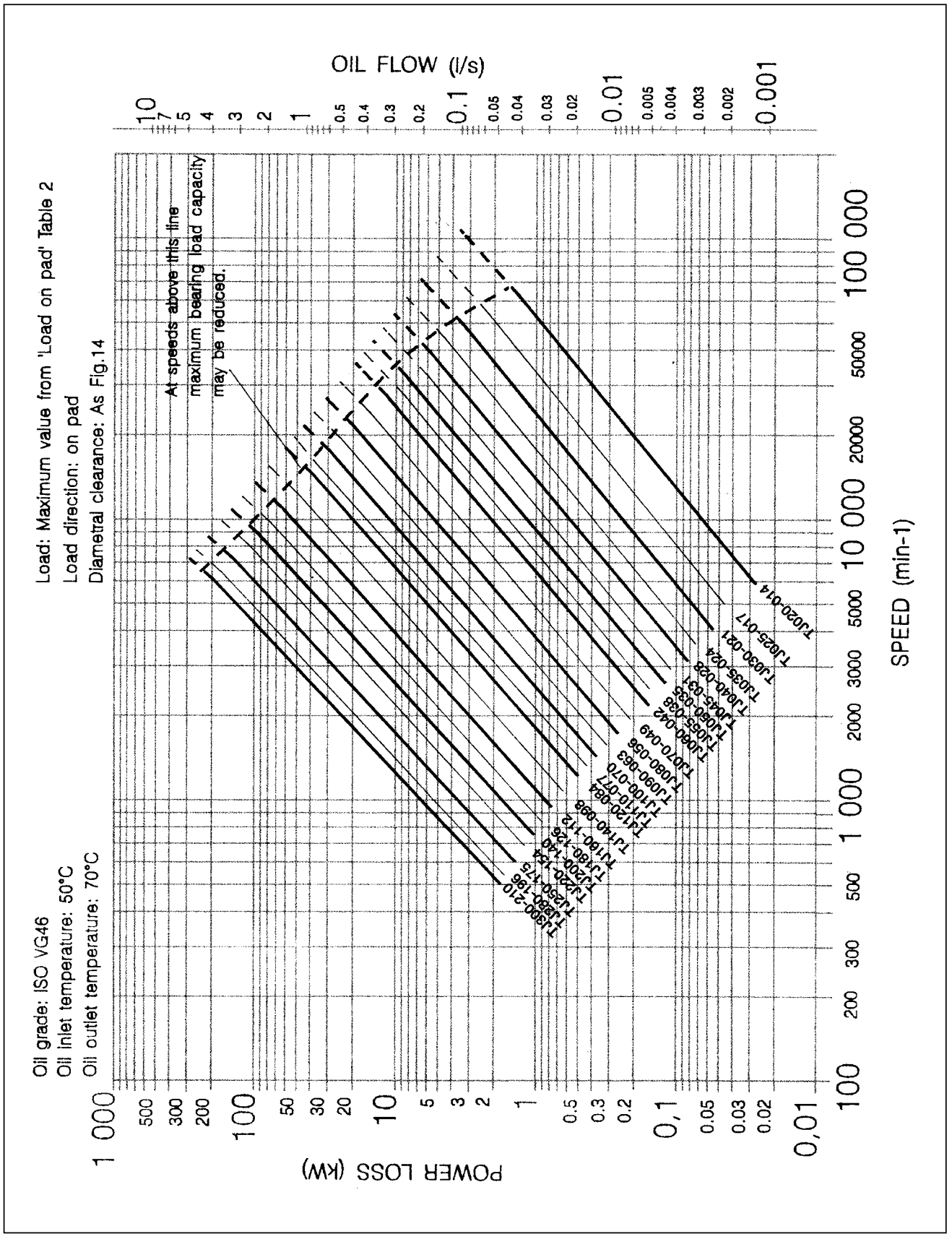


Fig 4(b) Power loss and Oil Flow. TJ series. B/D = 0.7

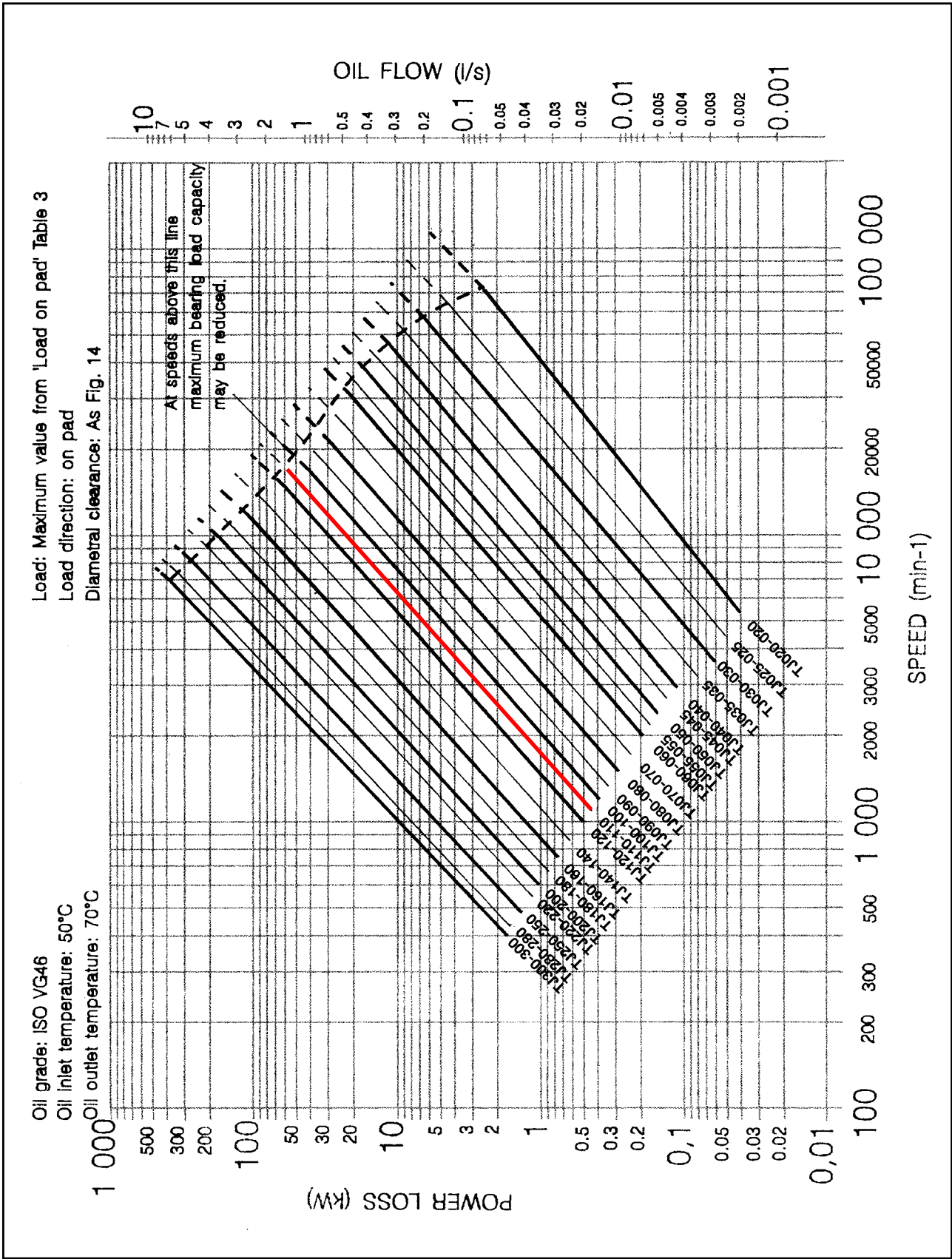


Fig 4(c) Power loss and Oil Flow. TJ series.B/D = 1.0

Příloha 3: výsledky hřidelů z programu KISSOFT

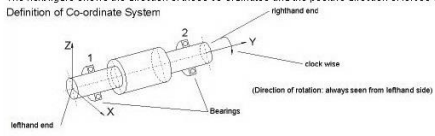
(pouze ukázka zbytek se nachází na přiloženém CD)

Sense of rotation

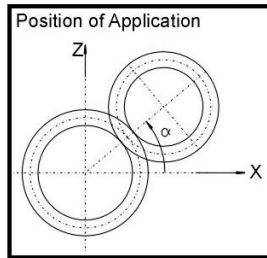
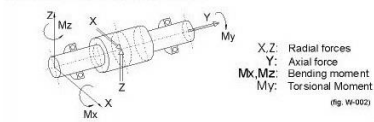
The shaft axis runs along the positive y -direction (left to right in the graphical Shaft editor). In the Shaft editor, the Z -axis points upwards, the X -axis points towards the user. A right-hand rotation of the shaft around the positive y -axis direction is specified as "clockwise".

The next figure shows the direction of these co-ordinates and the positive direction of forces and moments. Please note that weight has an effect in the negative Z -direction if the shaft is positioned horizontally.

Definition of Co-ordinate System



Positive Direction of Forces and Moments



In most force elements, the directions of the moments is usually defined by the terms "driving" and "driven". The entry "driving" means either that the shaft drives (an external application) or that the torque runs counter to the sense of rotation (i.e. the shaft loses power). The entry "driven" means either that the shaft is driven from outside (e.g. by a motor) or that the torque runs in the same direction as the sense of rotation (i.e. the shaft is supplied with power).

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_____ File _____
Name : hridel_z1
Changed by : jirisuch on: 14.03.2014 at: 17:33:51

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	1073.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	165.288
Mass moment of inertia (kg*m ²)	0.898
Momentum of mass GD2 (Nm ²)	35.218
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

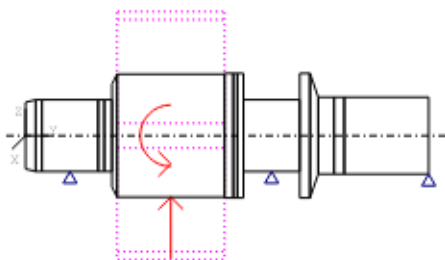
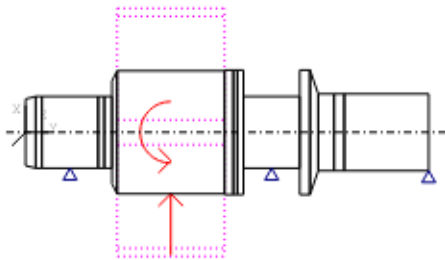


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone)	y= 0.00...20.00 (mm)
dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 20.00...32.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 32.00...142.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 1.8	
Cylinder (Cylinder)	y= 142.00...154.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 154.00...169.00 (mm)
d=140.00 (mm), l=15.00 (mm), Rz= 8.0	
Taper (Cone)	y= 169.00...179.00 (mm)
dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	
Cylinder (z1 nahrada)	y= 179.00...389.00 (mm)
d=240.00 (mm), l=210.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 389.00...406.00 (mm)
d=243.00 (mm), l=17.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 406.00...414.00 (mm)
d=243.00 (mm), l=8.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 414.00...426.00 (mm)
d=243.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 426.00...536.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 2.8	
Relief groove left (Relief groove left)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder)	y= 536.00...556.00 (mm)
d=243.00 (mm), l=20.00 (mm), Rz=32.0	
Taper (Cone)	y= 556.00...572.00 (mm)
dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 572.00...603.00 (mm)
d=150.00 (mm), l=31.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 603.00...623.00 (mm)
d=150.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 623.00...788.00 (mm)
d=150.00 (mm), l=165.00 (mm), Rz=16.0	

Inner contour

Forces

Cylindrical gear (z1 i12)	y= 284.00 (mm)	
Operating pitch diameter (mm)	484.1053	
Helix angle (°)	25.0375	Double helical gearing, right-left
Working pressure angle at normal section(°)	20.2194	
Position of contact point (°)	180.0000	
Length of load application (mm)	210.0000	
Power (kW)	510.2463	driving (Output)
Torque (Nm)	4541.0000	
Axial force (N)	0.0000	
Shearing force X (N)	7626.3126	
Shearing force Z (N)	18760.3827	
Bending moment X (Nm)	0.0000	
Bending moment Z (Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 3.58 µm (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 371.1 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.03 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	-3.813	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-8.937	kN	
Bearing reaction force	[Fr]	9.716	kN	(-113.11°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.011	mrاد	(0.04')
Misalignment of bearing	[ry]	0.450	mrاد	(1.55')
Misalignment of bearing	[rz]	-0.004	mrاد	(-0.02')
Misalignment of bearing	[rr]	0.012	mrاد	(0.04')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	-3.813	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-8.201	kN	
Bearing reaction force	[Fr]	9.044	kN	(-114.94°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.010	mrاد	(-0.03')
Misalignment of bearing	[ry]	0.342	mrاد	(1.18')
Misalignment of bearing	[rz]	0.004	mrاد	(0.01')
Misalignment of bearing	[rr]	0.011	mrاد	(0.04')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-4541.00	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	-0.001	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.003	mm	
Displacement of bearing	[ur]	0.004	mm	(-108.75°)
Misalignment of bearing	[rx]	-0.011	mrاد	(-0.04')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.004	mrاد	(0.01')

Misalignment of bearing [rr] 0.012 mrad (0.04')

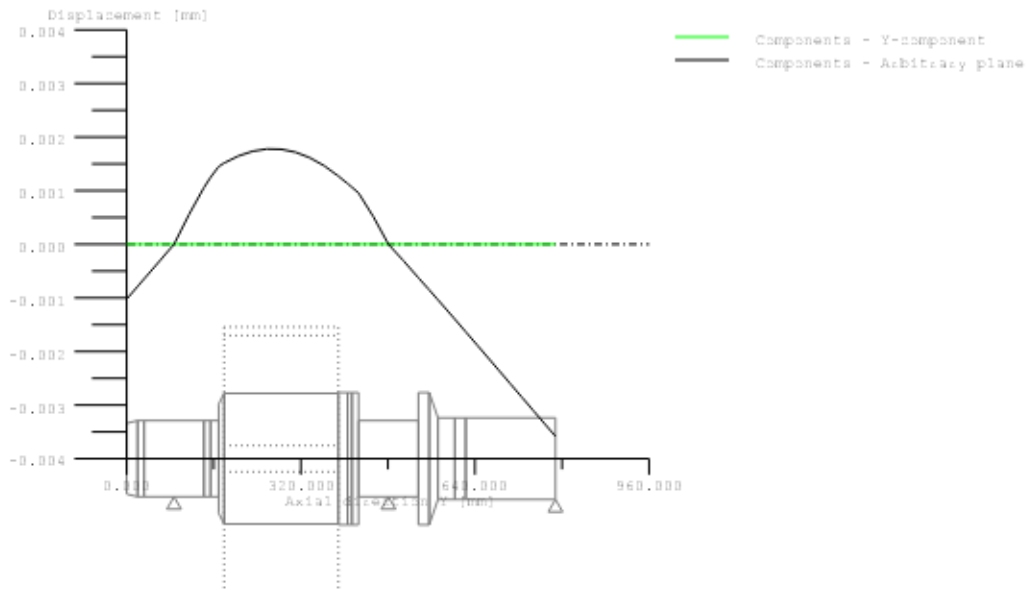
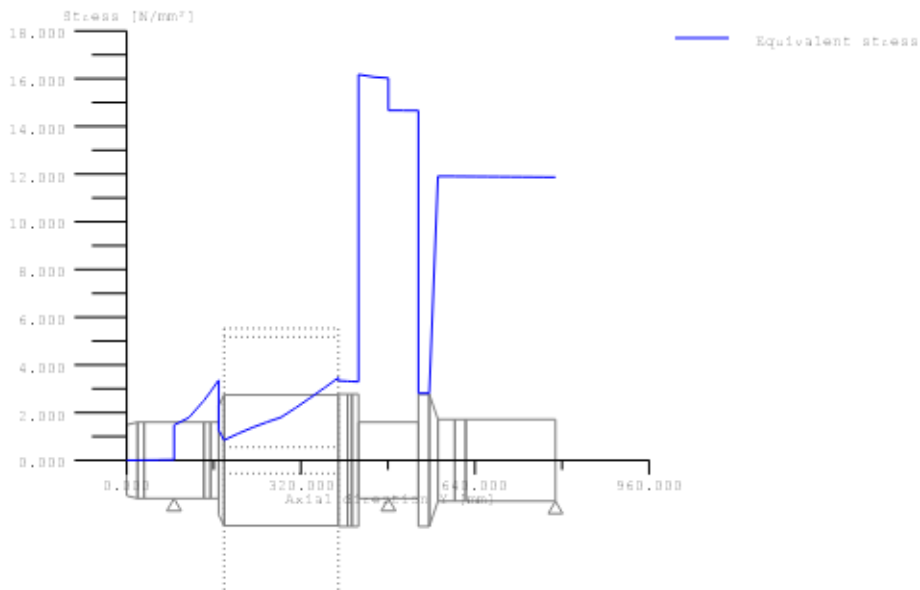


Figure: Displacement (bending etc.) (Arbitrary plane 71.25031329 °)



$$\text{GEH(von Mises): } \sigma_V = \left((\sigma_B + \sigma_Z, D)^2 + 3 * (\tau_T + \tau_S)^2 \right)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.80	60.43	79.14
3	3.32	0.87	0.80	10.76	16.06
2	3.32	0.87	0.80	9.71	15.93

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

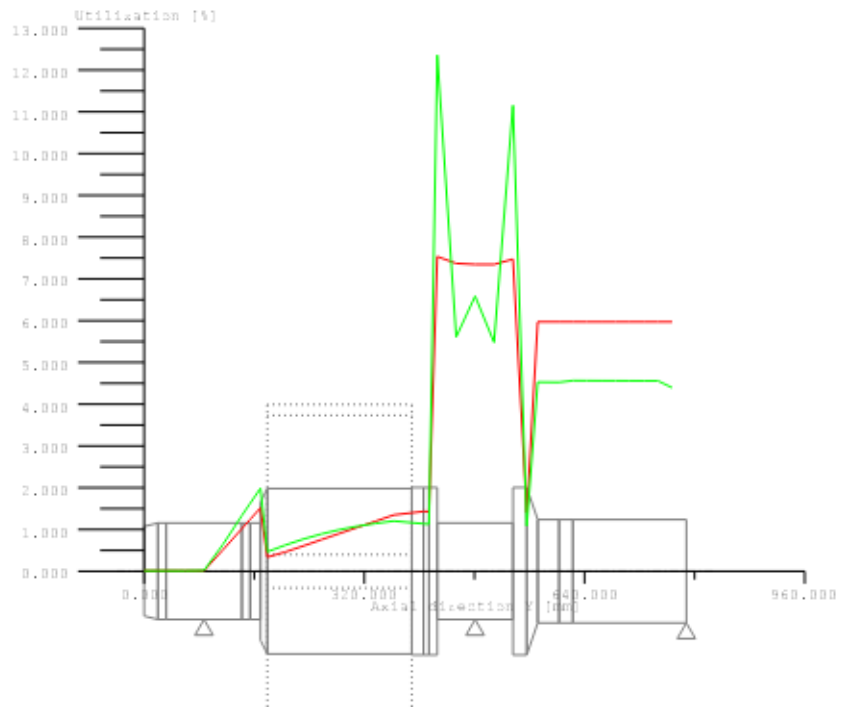


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 1073.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 250.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 482.72
 [sigSeff] (N/mm²) 337.91
 [sigbF] (N/mm²) 405.49
 [tautF] (N/mm²) 234.11
 [sigzdW] (N/mm²) 193.09
 [sigbW] (N/mm²) 241.36
 [tautW] (N/mm²) 144.82

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	811.9	0.0	9890.7
Maximum value	0.0	1380.3	0.0	16814.1
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	3.014	0.000	0.857
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	0.000	5.124	0.000	1.456

Technological size influence	[K1 (sigB)]	0.690
	[K1 (sigS)]	0.690

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) =	0.0		
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.924	0.956
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.082	1.325

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	0.000		
Equivalent mean stress (N/mm ²)	[taumV]	0.000		
Fatigue limit of part (N/mm ²)	[sigWK]	178.410	182.143	112.387
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.227	0.233	0.132
Permissible amplitude (N/mm ²)	[sigADK]	178.410	182.143	112.387
Margin of safety endurance limit	[S]		60.434	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		5036.1	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	337.907	405.489	234.109
Margin of safety yield stress	[S]		79.140	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		6595.0	

Cross section '3' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]	536.00			
External diameter (mm)	[da]	140.000			
Inner diameter (mm)	[di]	0.000			
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]				32.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	43.9	2270.5	420.0
Maximum value	-0.0	74.6	7719.7	714.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.166	4.287	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.282	14.576	0.063

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.052	10.185	46.858
Margin of safety endurance limit	[S]		10.761	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		896.7	
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		16.060	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1338.3	

Cross section '2' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]		426.00		
External diameter (mm)	[da]		140.000		
Inner diameter (mm)	[di]		0.000		
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]		32.000		
				Tension/Compression	Bending Torsion Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	585.4	2270.5	9550.3
Maximum value		-0.0	995.2	7719.7	16235.4
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4
Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	2.211	4.287	0.837
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	3.758	14.576	1.422

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.052	46.785	46.858
Margin of safety endurance limit	[S]		9.711	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		809.3	

Present margin of safety
for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		15.928	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1327.3	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
The reference diameter for the notch number is not defined.
Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
The notching factor for the light fit case is no longer defined in DIN 743.
The values are imported from the FKM-Guideline..

End report

lines: 531

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z11
Changed by : jirisuch on: 14.03.2014 at: 17:36:54

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	324.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	371.555
Mass moment of inertia (kg*m ²)	7.986
Momentum of mass GD2 (Nm ²)	313.366
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

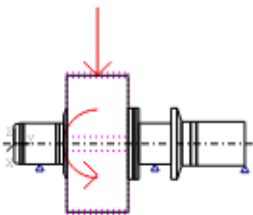
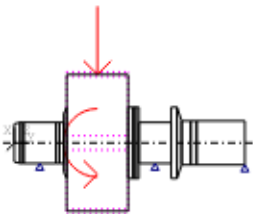


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone)	y= 0.00...20.00 (mm)
dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 20.00...32.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 32.00...142.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 1.8	
Cylinder (Cylinder)	y= 142.00...154.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 154.00...169.00 (mm)
d=140.00 (mm), l=15.00 (mm), Rz= 8.0	
Taper (Cone)	y= 169.00...179.00 (mm)
dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	
Cylinder (z1 nahrada)	y= 179.00...389.00 (mm)
d=466.18 (mm), l=210.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 389.00...406.00 (mm)
d=243.00 (mm), l=17.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 406.00...414.00 (mm)
d=243.00 (mm), l=8.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 414.00...426.00 (mm)
d=243.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 426.00...536.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 2.8	
Relief groove left (Relief groove left)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder)	y= 536.00...556.00 (mm)
d=243.00 (mm), l=20.00 (mm), Rz=32.0	
Taper (Cone)	y= 556.00...572.00 (mm)
dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 572.00...603.00 (mm)
d=150.00 (mm), l=31.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 603.00...623.00 (mm)
d=150.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 623.00...788.00 (mm)
d=150.00 (mm), l=165.00 (mm), Rz=16.0	

Inner contour

Forces

Cylindrical gear (z1 i21)	y= 284.00 (mm)		
Operating pitch diameter	(mm)	484.1053	
Helix angle	(°)	25.0375	Double helical gearing, right-left
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driving (Output)
Torque	(Nm)	15038.5586	
Axial force	(N)	0.0000	
Shearing force X	(N)	-25256.2760	
Shearing force Z	(N)	-62129.2921	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 5.98 µm (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 322.8 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.08 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	12.628	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	32.520	kN	
Bearing reaction force	[Fr]	34.886	kN	(68.78°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.026	mrاد	(-0.09')
Misalignment of bearing	[ry]	1.434	mrاد	(4.93')
Misalignment of bearing	[rz]	0.010	mrاد	(0.04')
Misalignment of bearing	[rr]	0.028	mrاد	(0.1')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	12.628	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	33.256	kN	
Bearing reaction force	[Fr]	35.573	kN	(69.21°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.019	mrاد	(0.07')
Misalignment of bearing	[ry]	1.133	mrاد	(3.89')
Misalignment of bearing	[rz]	-0.008	mrاد	(-0.03')
Misalignment of bearing	[rr]	0.021	mrاد	(0.07')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-15038.56	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.002	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.005	mm	
Displacement of bearing	[ur]	0.006	mm	(66.51°)
Misalignment of bearing	[rx]	0.018	mrاد	(0.06')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	-0.008	mrاد	(-0.03')

Misalignment of bearing [rr] 0.019 mrad (0.07')

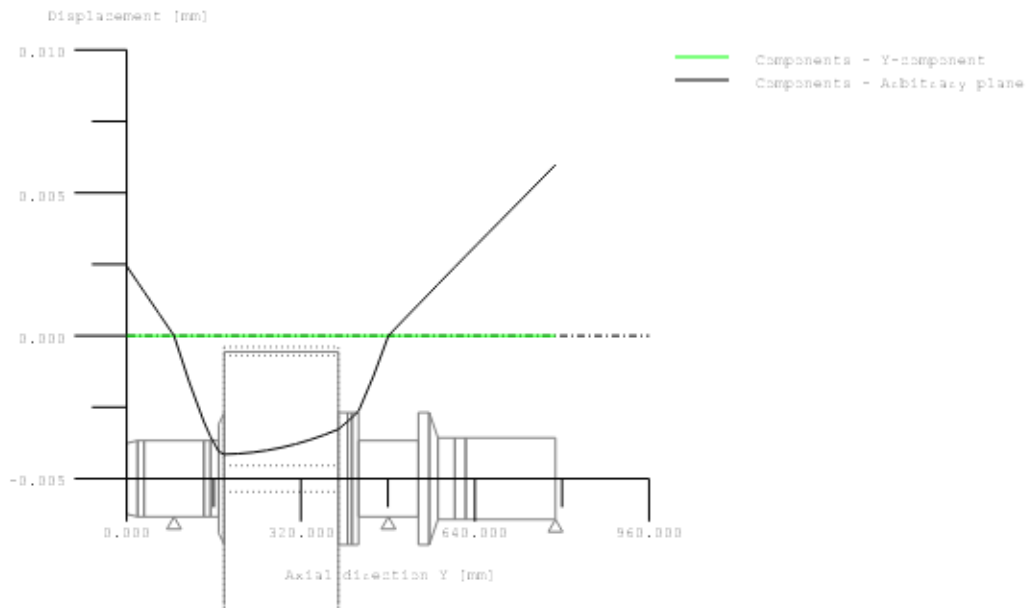
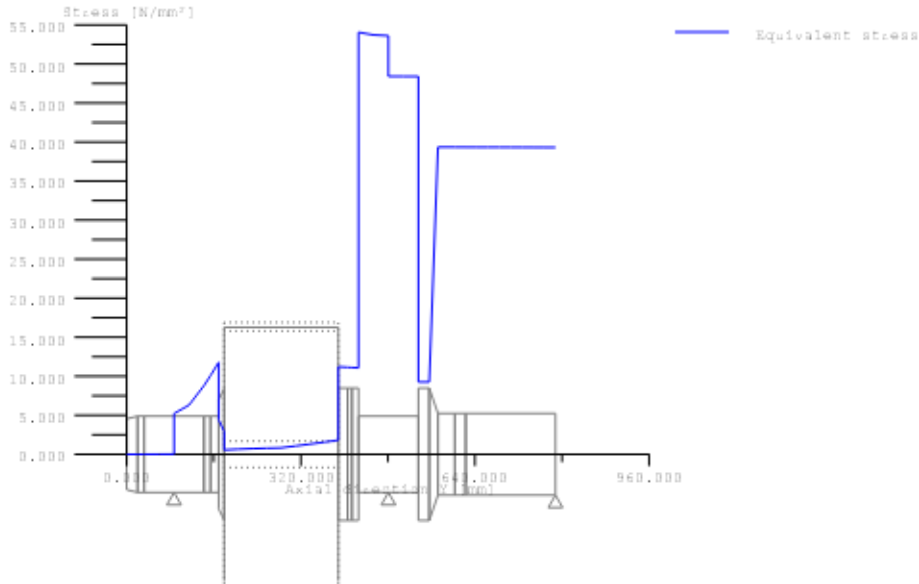


Figure: Displacement (bending etc.) (Arbitrary plane 66.51247504 °)



$$\text{GEH(von Mises): } \sigma_V = ((\sigma_B + \sigma_Z, D)^2 + 3 * (\tau_T + \tau_S)^2)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.93	0.80	16.79	21.94
3	3.30	0.88	0.80	3.17	4.71
2	3.30	0.88	0.80	2.88	4.68

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

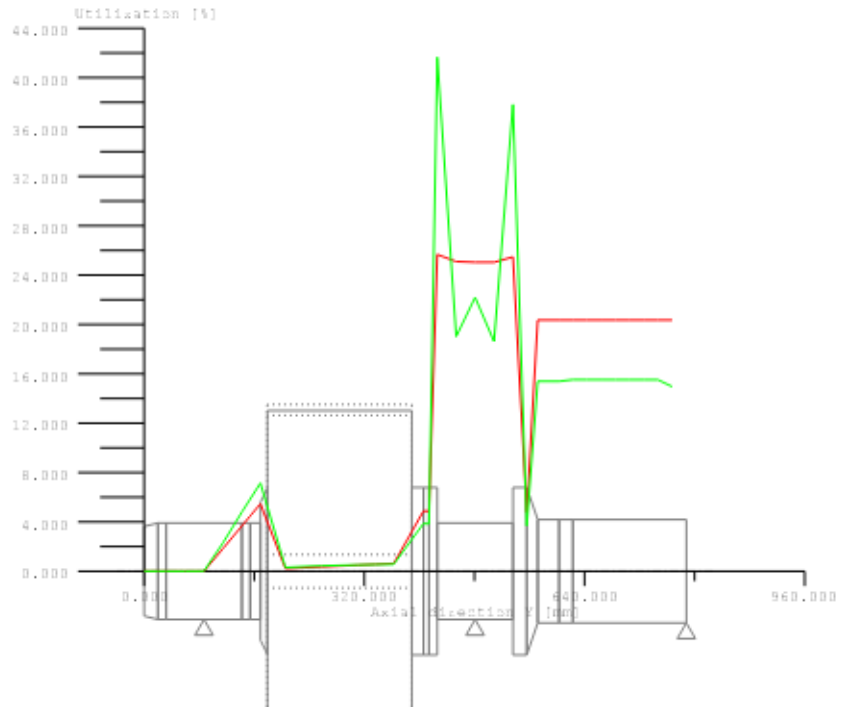


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 324.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 470.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 469.00
 [sigSeff] (N/mm²) 328.30
 [sigbF] (N/mm²) 393.96
 [tautF] (N/mm²) 227.45
 [sigzdW] (N/mm²) 187.60
 [sigbW] (N/mm²) 234.50
 [tautW] (N/mm²) 140.70

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	2844.8	0.0	34709.1
Maximum value	0.0	4836.2	0.0	59005.5
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	10.560	0.000	3.006
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	0.000	17.952	0.000	5.111

Technological size influence	[K1 (sigB)]	0.670
	[K1 (sigS)]	0.670

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.926	0.958
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.079	1.322

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	0.000		
Equivalent mean stress (N/mm ²)	[taumV]	0.000		
Fatigue limit of part (N/mm ²)	[sigWK]	173.804	177.353	109.324
Influence coeff. mean stress sensitivity.	[PsisigK]	0.227	0.233	0.132
Permissible amplitude (N/mm ²)	[sigADK]	173.804	177.353	109.324
Margin of safety endurance limit	[S]		16.795	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1399.6	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	328.300	393.960	227.453
Margin of safety yield stress	[S]		21.945	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1828.7	

Cross section '3' Shoulder with relief groove

Comment				
Position (Y-Coordinate) (mm)	[y]	536.00		
External diameter (mm)	[da]	140.000		
Inner diameter (mm)	[di]	0.000		
Notch effect Shoulder with relief groove				
[D, d, D1, r, t] (mm)		243.00	139.20	140.00
Shape B			1.20	0.40
Mean roughness (µm)	[Rz]		32.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	7519.3	0.0
Amplitude	0.0	43.9	7519.3	420.0
Maximum value	-0.0	74.6	25565.5	714.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	14.198	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.166	14.198	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.282	48.273	0.063

Technological size influence	[K1 (sigB)]	0.670		
	[K1 (sigS)]	0.670		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.224	1.224	1.158
Notch effect coefficient	[beta]	3.924	3.298	2.287
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.877	0.877	0.930
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.064	4.238	2.918

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	24.592		
Equivalent mean stress (N/mm ²)	[taumV]	14.198		
Fatigue limit of part (N/mm ²)	[sigWK]	46.164	55.327	48.222
Influence coeff. mean stress sensitivity.	[PsisigK]	0.052	0.063	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.015	3.034	45.743
Margin of safety endurance limit	[S]		3.173	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		264.4	

Present margin of safety for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	377.545	453.054	227.453
Margin of safety yield stress	[S]		4.712	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		392.6	

Cross section '2' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]		426.00		
External diameter (mm)	[da]		140.000		
Inner diameter (mm)	[di]		0.000		
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]		32.000		

			Tension/Compression	Bending Torsion	Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	7519.3	0.0
Amplitude		0.0	1867.5	7519.3	35054.1
Maximum value		-0.0	3174.8	25565.5	59591.9
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4

Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	14.198	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	7.053	14.198	3.071
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	11.989	48.273	5.221

Technological size influence	[K1 (sigB)]	0.670		
	[K1 (sigS)]	0.670		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.224	1.224	1.158
Notch effect coefficient	[beta]	3.924	3.298	2.287
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.877	0.877	0.930
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.064	4.238	2.918

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	24.592		
Equivalent mean stress (N/mm ²)	[taumV]	14.198		
Fatigue limit of part (N/mm ²)	[sigWK]	46.164	55.327	48.222
Influence coeff. mean stress sensitivity.	[PsisigK]	0.052	0.063	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.015	45.403	45.743
Margin of safety endurance limit	[S]		2.881	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		240.1	

Present margin of safety
 for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	377.545	453.054	227.453
Margin of safety yield stress	[S]		4.676	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		389.6	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
 The reference diameter for the notch number is not defined.
 Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
 The notching factor for the light fit case is no longer defined in DIN 743.
 The values are imported from the FKM-Guideline..

End report

lines: 531

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z2
Changed by : jirisuch on: 14.03.2014 at: 17:38:01

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	3561.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	66.039
Mass moment of inertia (kg*m ²)	0.119
Momentum of mass GD2 (Nm ²)	4.656
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

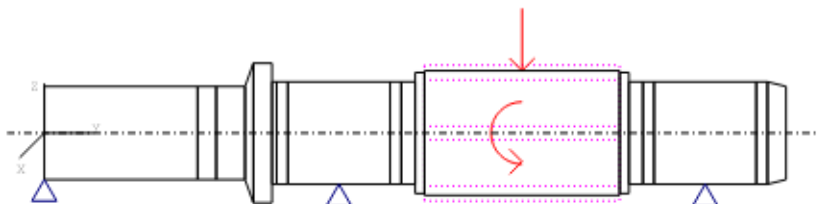
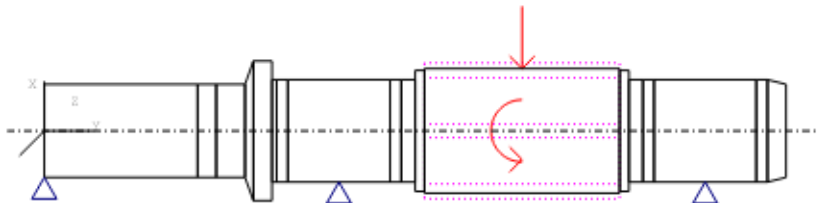


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z2 nahrada) d=133.83 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z2 i12)			y= 514.00 (mm)
Operating pitch diameter	(mm)	145.8947	
Helix angle	(°)	25.0375	Double helical gearing, left-right
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	1368.2935	
Axial force	(N)	0.0000	
Shearing force X	(N)	-7625.0471	
Shearing force Z	(N)	-18757.2696	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 20.54 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 414.8 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.04 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm	
Bearing reaction force	[Fx]	3.813	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	9.856	kN	
Bearing reaction force	[Fr]	10.568	kN	(68.85°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.061	mrاد	(-0.21')
Misalignment of bearing	[ry]	0.480	mrاد	(1.65')
Misalignment of bearing	[rz]	0.025	mrاد	(0.09')
Misalignment of bearing	[rr]	0.066	mrاد	(0.23')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm	
Bearing reaction force	[Fx]	3.813	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	9.549	kN	
Bearing reaction force	[Fr]	10.282	kN	(68.24°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.063	mrاد	(0.22')
Misalignment of bearing	[ry]	0.642	mrاد	(2.21')
Misalignment of bearing	[rz]	-0.025	mrاد	(-0.09')
Misalignment of bearing	[rr]	0.068	mrاد	(0.23')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	0.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-1368.29	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.008	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.019	mm	
Displacement of bearing	[ur]	0.021	mm	(66.84°)
Misalignment of bearing	[rx]	-0.059	mrاد	(-0.2')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.025	mrاد	(0.09')
Misalignment of bearing	[rr]	0.064	mrاد	(0.22')

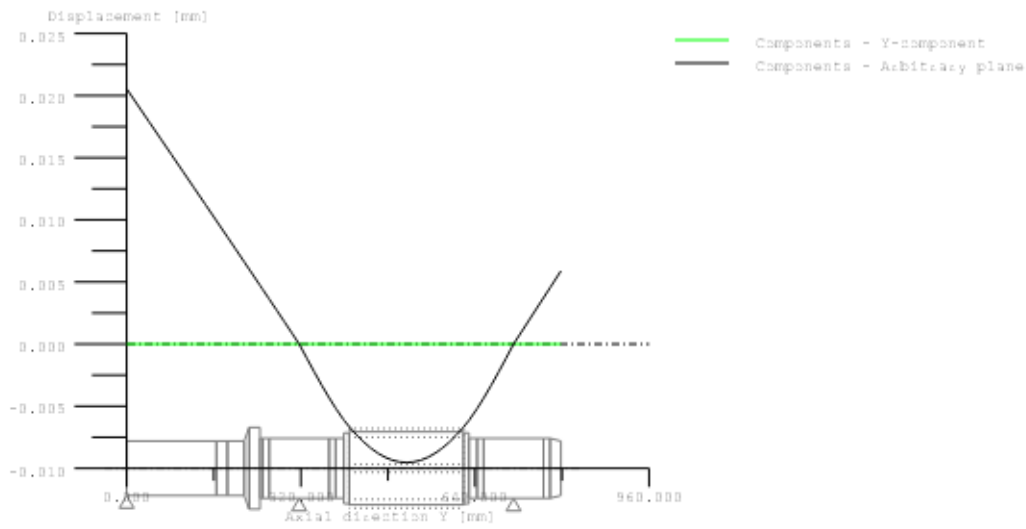
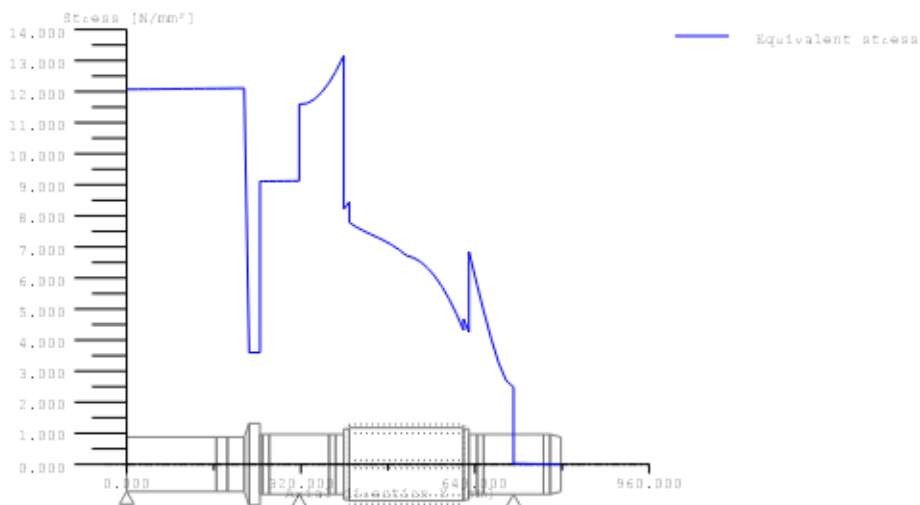
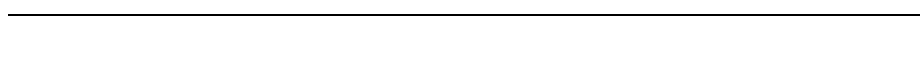


Figure: Displacement (bending etc.) (Arbitrary plane 66.84122152 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress



End report

lines: 220

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z22
Changed by : jirisuch on: 14.03.2014 at: 17:38:59

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	1073.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	66.039
Mass moment of inertia (kg*m ²)	0.119
Momentum of mass GD2 (Nm ²)	4.656
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

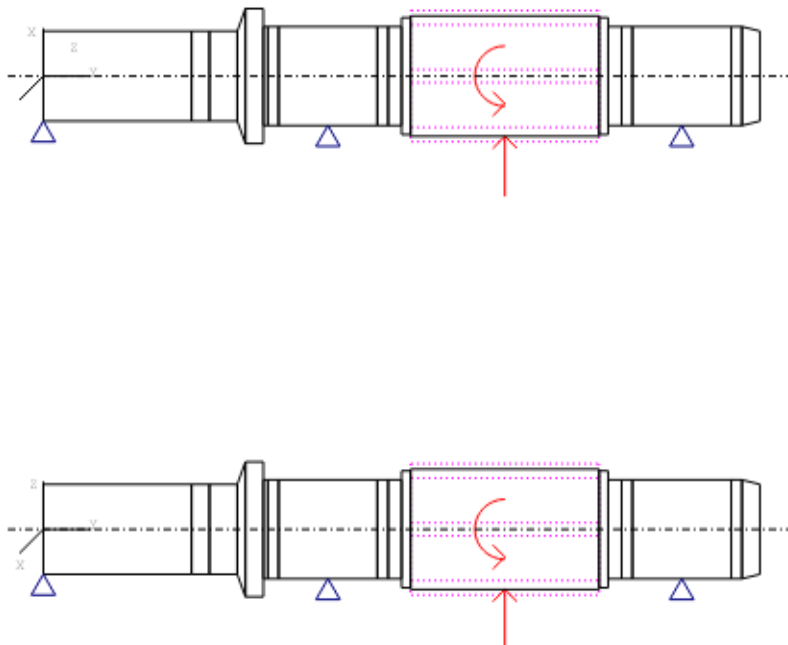


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z2 nahrada) d=133.83 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z2 i21)			y= 514.00 (mm)
Operating pitch diameter	(mm)	145.8947	
Helix angle	(°)	25.0375	Double helical gearing, left-right
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	4541.0000	
Axial force	(N)	0.0000	
Shearing force X	(N)	25305.4919	
Shearing force Z	(N)	62250.3608	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 72.09 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 414.8 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.12 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm	
Bearing reaction force	[Fx]	-12.653	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-30.648	kN	
Bearing reaction force	[Fr]	33.157	kN	(-112.43°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.209	mrاد	(0.72')
Misalignment of bearing	[ry]	1.592	mrاد	(5.47')
Misalignment of bearing	[rz]	-0.085	mrاد	(-0.29')
Misalignment of bearing	[rr]	0.226	mrاد	(0.78')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm	
Bearing reaction force	[Fx]	-12.653	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-30.954	kN	
Bearing reaction force	[Fr]	33.441	kN	(-112.23°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.208	mrاد	(-0.71')
Misalignment of bearing	[ry]	2.131	mrاد	(7.32')
Misalignment of bearing	[rz]	0.085	mrاد	(0.29')
Misalignment of bearing	[rr]	0.224	mrاد	(0.77')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	0.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-4541.00	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	-0.027	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.067	mm	
Displacement of bearing	[ur]	0.072	mm	(-111.83°)
Misalignment of bearing	[rx]	0.212	mrاد	(0.73')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	-0.085	mrاد	(-0.29')
Misalignment of bearing	[rr]	0.228	mrاد	(0.78')

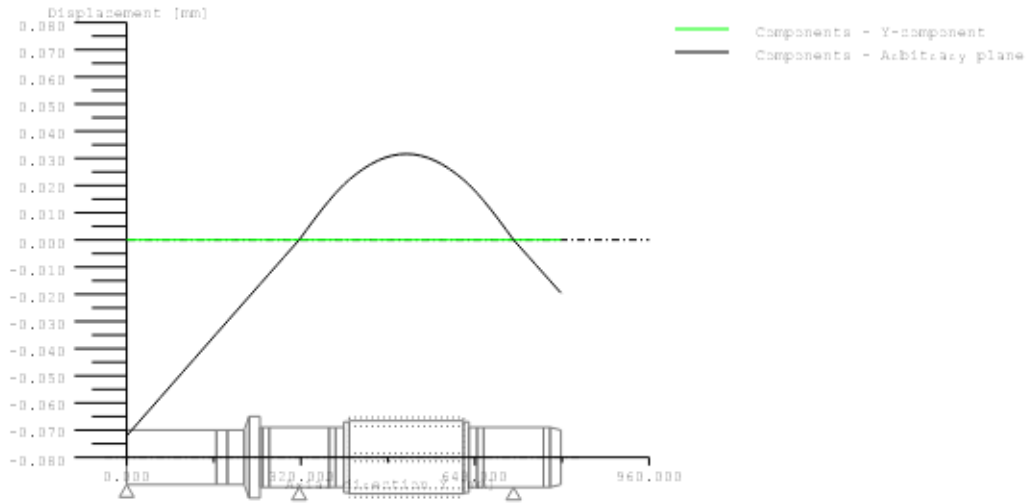
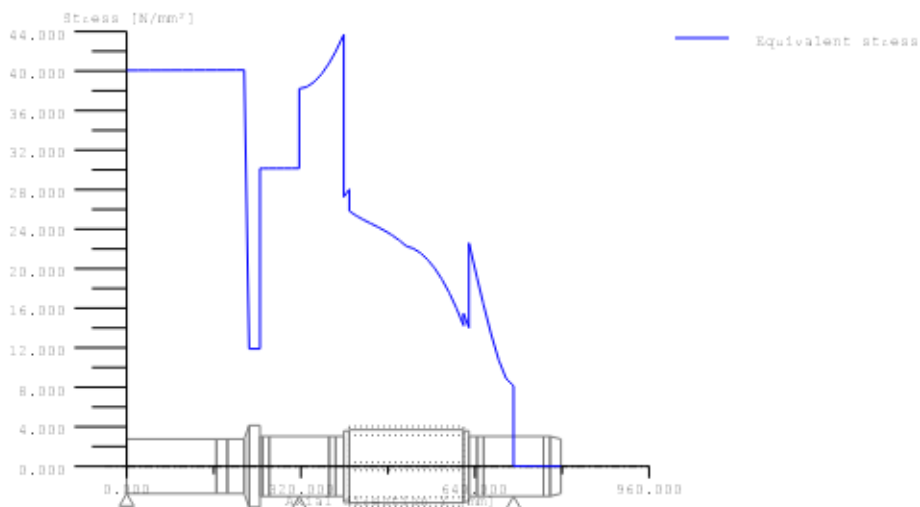


Figure: Displacement (bending etc.) (Arbitrary plane 68.17292967 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress

**Strength calculation as specified in
 DIN 743:2000**

Summary

Label Shaft 1
 Drawing

Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

Calculation of endurance limit and the static strength
 Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	245.10	Smooth shaft
2	317.00	Smooth shaft
3	399.00	Own Input
4	629.00	Own Input
5	655.00	Smooth shaft
6	766.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.82	11.41	8.50
2	1.00	0.92	0.82	11.40	8.50
3	1.00	0.92	0.82	6.73	6.96
4	1.00	0.92	0.82	9.40	12.16
5	1.00	0.92	0.82	13.77	17.80
6	1.00	0.92	0.82	10000.00	10000.00

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
 Kfsig: Surface factor
 K2d: Size coefficient bending
 SD: Safety endurance limit
 SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

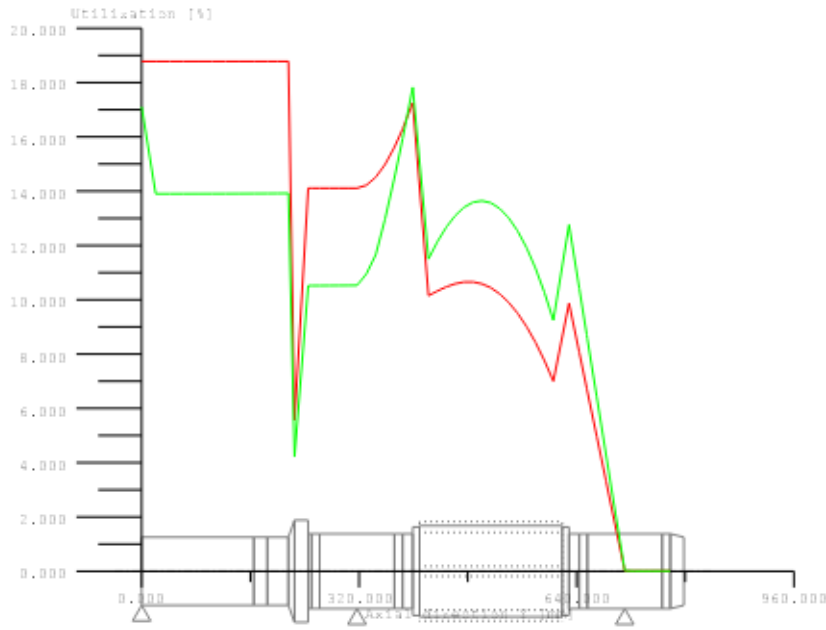


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 798.00
 Speed (1/min) [n] 1073.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 160.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 518.00
 [sigSeff] (N/mm²) 362.60
 [sigbF] (N/mm²) 435.12
 [tautF] (N/mm²) 251.22
 [sigzdW] (N/mm²) 207.20
 [sigbW] (N/mm²) 259.00
 [tautW] (N/mm²) 155.40

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	245.10
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	18.3	2270.5	166.3
Maximum value	-0.0	31.2	7719.7	282.7
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.140	8.688	0.023
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.239	29.539	0.040

Technological size influence	[K1 (sigB)]	0.740
	[K1 (sigS)]	0.740

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821
Influence coefficient surface roughness	[KF]	0.918	0.918
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.089	1.308

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	190.186	198.024	122.553
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.225	0.236	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.024	4.023	108.056
Margin of safety endurance limit	[S]		11.409	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		950.7	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	362.600	435.120	251.217
Margin of safety yield stress	[S]		8.505	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		708.7	

Cross section '2' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	317.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	32.2	2270.5	213.8
Maximum value	-0.0	54.7	7719.7	363.4
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.246	8.688	0.030
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.419	29.539	0.051

Technological size influence	[K1 (sigB)]	0.740
	[K1 (sigS)]	0.740

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.918	0.918	0.953
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.089	1.308	1.268

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	190.186	198.024	122.553
Influence coeff. mean stress sensitivity.	[PsisigK]	0.225	0.236	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.024	7.007	108.056
Margin of safety endurance limit	[S]		11.396	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		949.7	

Present margin of safety for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	362.600	435.120	251.217
Margin of safety yield stress	[S]		8.504	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		708.7	

Cross section '3' Own Input

Comment		
Position (Y-Coordinate) (mm)	[y]	399.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Own Input		
Mean roughness (µm)	[Rz]	8.000

		Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	2767.5	2270.5	33409.7
Maximum value		-0.0	4704.8	7719.7	56796.5
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		9503.3	130671	261341	9503.3

Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	21.180	8.688	4.687
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	36.005	29.539	7.969

Technological size influence	[K1 (sigB)]	0.740
	[K1 (sigS)]	0.740

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.918	0.918	0.953
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.089	1.308	1.268

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	190.186	198.024	122.553
Influence coeff. mean stress sensitivity.	[PsisigK]	0.225	0.236	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.024	169.556	108.056
Margin of safety endurance limit	[S]		6.732	

Required safety	[Smin]	1.200		
Result (%)	[S/Smin]	561.0		
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	362.600	435.120	251.217
Margin of safety yield stress	[S]		6.955	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		579.6	

Cross section '4' Own Input

Comment				
Position (Y-Coordinate) (mm)	[y]		629.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Own Input				
Mean roughness (µm)	[Rz]		8.000	
Tension/Compression Bending Torsion Shearing				
Stress: (N) (Nm)				
Mean value		-0.0	0.0	0.0 0.0
Amplitude		0.0	2751.6	0.0 33558.3
Maximum value		-0.0	4677.7	0.0 57049.1
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]		9503.3	130671	261341 9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	0.000 0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	21.057	0.000 4.708
[sigzdmx, sigbmx, taumax, tauqmax] (N/mm ²)		-0.000	35.797	0.000 8.004

Technological size influence	[K1 (sigB)]		0.740	
	[K1 (sigS)]		0.740	

Tension/Compression Bending Torsion				
Notch effect coefficient	[beta (dB)]	0.000	0.000	0.000
[dB] (mm) = 0.0				
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.918	0.918	0.953
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.089	1.308	1.268

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	190.186	198.024	122.553
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.225	0.236	0.134
Permissible amplitude (N/mm ²)	[sigADK]	190.186	198.024	122.553
Margin of safety endurance limit	[S]		9.404	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		783.7	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	362.600	435.120	251.217
Margin of safety yield stress	[S]		12.155	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1012.9	

Cross section '5' Smooth shaft

Comment				
Position (Y-Coordinate) (mm)	[y]		655.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Smooth shaft				
Mean roughness (µm)	[Rz]		8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	1879.4	0.0	33539.7
Maximum value	-0.0	3195.0	0.0	57017.5
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	14.383	0.000	4.706
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	24.451	0.000	8.000

Technological size influence	[K1 (sigB)]	0.740
	[K1 (sigS)]	0.740

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821
Influence coefficient surface roughness	[KF]	0.918	0.918
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.089	1.308

Present margin of safety for endurance limit:			
Equivalent mean stress (N/mm ²)	[sigmV]	0.000	
Equivalent mean stress (N/mm ²)	[taumV]	0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	190.186	198.024
Influence coeff. mean stress sensitivity:			
	[PsisigK]	0.225	0.236
Permissible amplitude (N/mm ²)	[sigADK]	190.186	198.024
Margin of safety endurance limit	[S]	13.768	
Required safety	[Smin]	1.200	
Result (%)	[S/Smin]	1147.3	

Present margin of safety for proof against exceed of yield point:			
Static notch sensitivity factor	[K2F]	1.000	1.200
Increase coefficient	[gammaF]	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	362.600	435.120
Margin of safety yield stress	[S]	17.796	
Required safety	[Smin]	1.200	
Result (%)	[S/Smin]	1483.0	

Cross section '6' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	766.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	0.3	0.0	27.1
Maximum value	-0.0	0.6	0.0	46.1
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.003	0.000	0.004
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.004	0.000	0.006

Technological size influence	[K1 (sigB)]	0.740
	[K1 (sigS)]	0.740

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000

Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.918	0.918	0.953
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.089	1.308	1.268

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	190.186	198.024	122.553
Influence coeff. mean stress sensitivity.	[PsigK]	0.225	0.236	0.134
Permissible amplitude (N/mm ²)	[sigADK]	190.186	198.024	122.553
Margin of safety endurance limit	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety

for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	362.600	435.120	251.217
Margin of safety yield stress	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
The reference diameter for the notch number is not defined.
Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
The notching factor for the light fit case is no longer defined in DIN 743.
The values are imported from the FKM-Guideline..

End report

lines: 710

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z3
Changed by : jirisuch on: 14.03.2014 at: 17:40:05

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	1073.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	165.288
Mass moment of inertia (kg*m ²)	0.898
Momentum of mass GD2 (Nm ²)	35.218
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

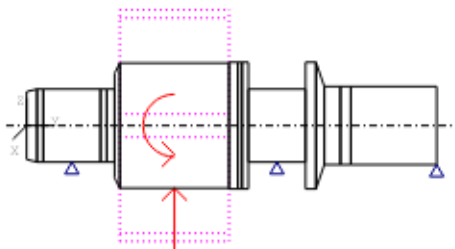
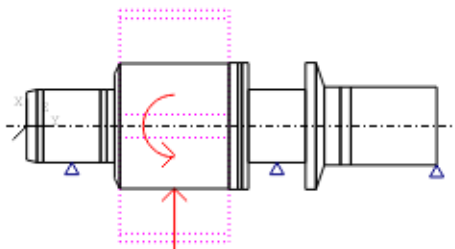


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone) dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	y= 0.00...20.00 (mm)
Cylinder (Cylinder) d=140.00 (mm), l=12.00 (mm), Rz= 8.0	y= 20.00...32.00 (mm)
Cylinder (Cylinder) d=140.00 (mm), l=110.00 (mm), Rz= 1.8	y= 32.00...142.00 (mm)
Cylinder (Cylinder) d=140.00 (mm), l=12.00 (mm), Rz= 8.0	y= 142.00...154.00 (mm)
Cylinder (Cylinder) d=140.00 (mm), l=15.00 (mm), Rz= 8.0	y= 154.00...169.00 (mm)
Taper (Cone) dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	y= 169.00...179.00 (mm)
Cylinder (z3 nahrada) d=240.00 (mm), l=210.00 (mm), Rz=32.0	y= 179.00...389.00 (mm)
Cylinder (Cylinder) d=243.00 (mm), l=17.00 (mm), Rz= 8.0	y= 389.00...406.00 (mm)
Cylinder (Cylinder) d=243.00 (mm), l=8.00 (mm), Rz= 8.0	y= 406.00...414.00 (mm)
Cylinder (Cylinder) d=243.00 (mm), l=12.00 (mm), Rz= 8.0	y= 414.00...426.00 (mm)
Cylinder (Cylinder) d=140.00 (mm), l=110.00 (mm), Rz= 2.8	y= 426.00...536.00 (mm)
Relief groove left (Relief groove left) r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0 Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right) r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0 Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder) d=243.00 (mm), l=20.00 (mm), Rz=32.0	y= 536.00...556.00 (mm)
Taper (Cone) dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	y= 556.00...572.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=31.00 (mm), Rz= 8.0	y= 572.00...603.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 603.00...623.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=165.00 (mm), Rz=16.0	y= 623.00...788.00 (mm)

Inner contour

Forces

Cylindrical gear (z3 i34)		y= 284.00 (mm)
Operating pitch diameter	(mm)	444.3158
Helix angle	(°)	25.0375
Working pressure angle at normal section(°)		20.2194
Position of contact point	(°)	180.0000
Length of load application	(mm)	210.0000
Power	(kW)	510.2463
Torque	(Nm)	4541.0000
Axial force	(N)	0.0000
Shearing force X	(N)	8309.2660
Shearing force Z	(N)	20440.4170
Bending moment X	(Nm)	0.0000
Bending moment Z	(Nm)	0.0000

Double helical gearing, right-left
driving (Output)

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 3.86 μm (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 371.1 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.03 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	-4.155	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-9.777	kN	
Bearing reaction force	[Fr]	10.623	kN	(-113.02°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.012	mrاد	(0.04')
Misalignment of bearing	[ry]	0.450	mrاد	(1.55')
Misalignment of bearing	[rz]	-0.005	mrاد	(-0.02')
Misalignment of bearing	[rr]	0.013	mrاد	(0.04')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	-4.155	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-9.041	kN	
Bearing reaction force	[Fr]	9.950	kN	(-114.68°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.011	mrاد	(-0.04')
Misalignment of bearing	[ry]	0.342	mrاد	(1.18')
Misalignment of bearing	[rz]	0.004	mrاد	(0.01')
Misalignment of bearing	[rr]	0.011	mrاد	(0.04')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-4541.00	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	-0.001	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.004	mm	
Displacement of bearing	[ur]	0.004	mm	(-108.99°)
Misalignment of bearing	[rx]	-0.012	mrاد	(-0.04')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.004	mrاد	(0.01')

Misalignment of bearing [rr] 0.013 mrad (0.04')

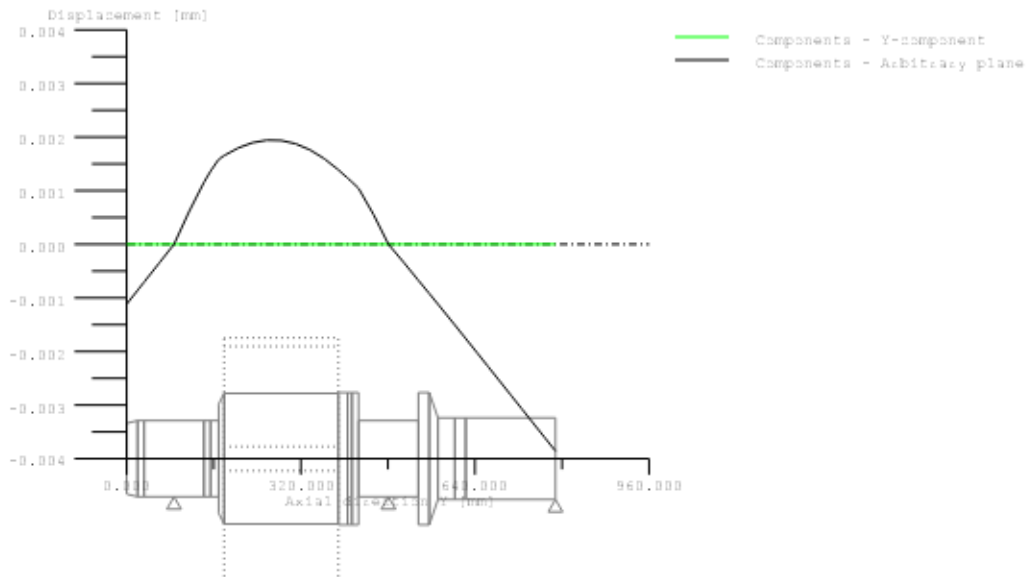
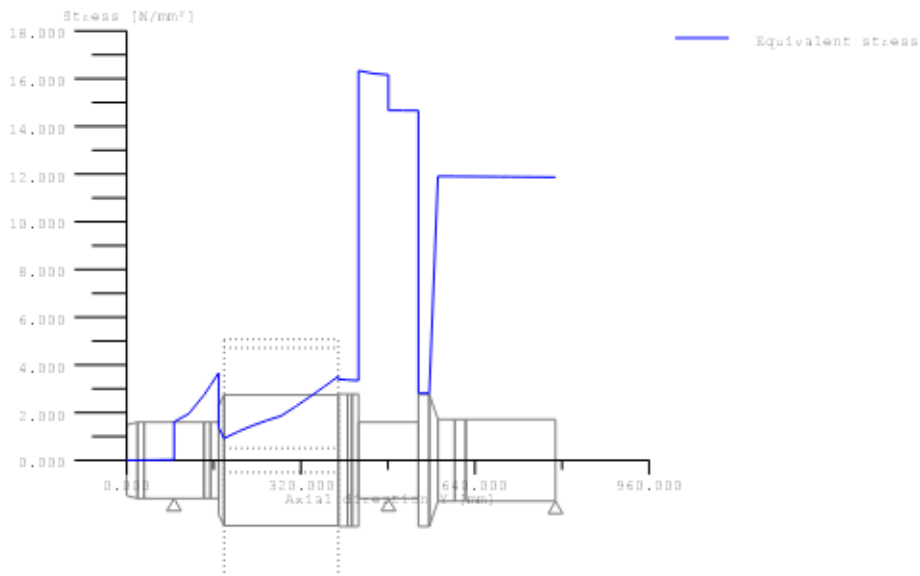


Figure: Displacement (bending etc.) (Arbitrary plane 71.01093494 °)



$$\text{GEH(von Mises): } \sigma_V = ((\sigma_B + \sigma_Z, D)^2 + 3 * (\tau_T + \tau_S)^2)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.80	55.36	72.50
3	3.32	0.87	0.80	10.76	16.06
2	3.32	0.87	0.80	9.57	15.90

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

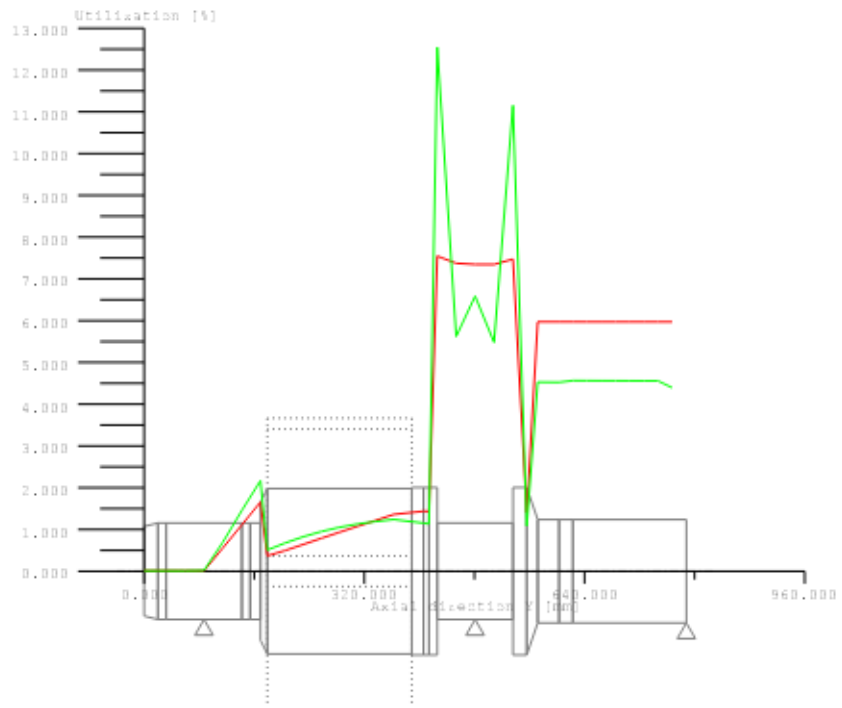


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 1073.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 250.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 482.72
 [sigSeff] (N/mm²) 337.91
 [sigbF] (N/mm²) 405.49
 [tautF] (N/mm²) 234.11
 [sigzdW] (N/mm²) 193.09
 [sigbW] (N/mm²) 241.36
 [tautW] (N/mm²) 144.82

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft
 Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	886.3	0.0	10797.4
Maximum value	0.0	1506.7	0.0	18355.6
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	3.290	0.000	0.935
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	0.000	5.593	0.000	1.590

Technological size influence	[K1 (sigB)]	0.690
	[K1 (sigS)]	0.690

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) =	0.0		
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.924	0.956
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.082	1.289

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	0.000		
Equivalent mean stress (N/mm ²)	[taumV]	0.000		
Fatigue limit of part (N/mm ²)	[sigWK]	178.410	182.143	112.387
Influence coeff. mean stress sensitivity.	[PsisigK]	0.227	0.233	0.132
Permissible amplitude (N/mm ²)	[sigADK]	178.410	182.143	112.387
Margin of safety endurance limit	[S]		55.364	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		4613.7	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	337.907	405.489	234.109
Margin of safety yield stress	[S]		72.502	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		6041.8	

Cross section '3' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]	536.00			
External diameter (mm)	[da]	140.000			
Inner diameter (mm)	[di]	0.000			
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]				32.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	43.9	2270.5	420.0
Maximum value	-0.0	74.6	7719.7	714.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.166	4.287	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.282	14.576	0.063

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.052	10.185	46.858
Margin of safety endurance limit	[S]		10.761	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		896.7	
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		16.060	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1338.3	

Cross section '2' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]		426.00		
External diameter (mm)	[da]		140.000		
Inner diameter (mm)	[di]		0.000		
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]		32.000		
				Tension/Compression	Bending Torsion Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	635.3	2270.5	10456.8
Maximum value		-0.0	1080.0	7719.7	17776.5
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4
Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	2.399	4.287	0.916
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	4.078	14.576	1.557

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.052	47.429	46.858
Margin of safety endurance limit	[S]		9.565	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		797.1	

Present margin of safety
for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		15.905	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1325.4	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
The reference diameter for the notch number is not defined.
Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
The notching factor for the light fit case is no longer defined in DIN 743.
The values are imported from the FKM-Guideline..

End report

lines: 531

_____ KISSsoft - Release 03-2012F _____
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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z33
Changed by : jirisuch on: 14.03.2014 at: 17:40:59

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	449.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	165.288
Mass moment of inertia (kg*m ²)	0.898
Momentum of mass GD2 (Nm ²)	35.218
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

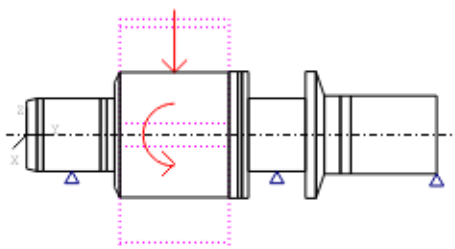
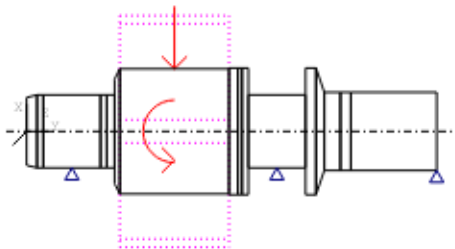


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone)	y= 0.00...20.00 (mm)
dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 20.00...32.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 32.00...142.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 1.8	
Cylinder (Cylinder)	y= 142.00...154.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 154.00...169.00 (mm)
d=140.00 (mm), l=15.00 (mm), Rz= 8.0	
Taper (Cone)	y= 169.00...179.00 (mm)
dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	
Cylinder (z3 nahrada)	y= 179.00...389.00 (mm)
d=240.00 (mm), l=210.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 389.00...406.00 (mm)
d=243.00 (mm), l=17.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 406.00...414.00 (mm)
d=243.00 (mm), l=8.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 414.00...426.00 (mm)
d=243.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 426.00...536.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 2.8	
Relief groove left (Relief groove left)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder)	y= 536.00...556.00 (mm)
d=243.00 (mm), l=20.00 (mm), Rz=32.0	
Taper (Cone)	y= 556.00...572.00 (mm)
dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 572.00...603.00 (mm)
d=150.00 (mm), l=31.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 603.00...623.00 (mm)
d=150.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 623.00...788.00 (mm)
d=150.00 (mm), l=165.00 (mm), Rz=16.0	

Inner contour

Forces

Cylindrical gear (z3 i43)	y= 284.00 (mm)		
Operating pitch diameter	(mm)	444.3158	
Helix angle	(°)	25.0375	Double helical gearing, right-left
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driving (Output)
Torque	(Nm)	10851.8775	
Axial force	(N)	0.0000	
Shearing force X	(N)	-19857.1100	
Shearing force Z	(N)	-48847.5889	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 7.45 µm (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 371.1 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.06 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	9.929	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	24.867	kN	
Bearing reaction force	[Fr]	26.776	kN	(68.24°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.029	mrاد	(-0.1')
Misalignment of bearing	[ry]	1.076	mrاد	(3.7')
Misalignment of bearing	[rz]	0.012	mrاد	(0.04')
Misalignment of bearing	[rr]	0.031	mrاد	(0.11')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	9.929	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	25.603	kN	
Bearing reaction force	[Fr]	27.461	kN	(68.8°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.023	mrاد	(0.08')
Misalignment of bearing	[ry]	0.817	mrاد	(2.81')
Misalignment of bearing	[rz]	-0.010	mrاد	(-0.03')
Misalignment of bearing	[rr]	0.025	mrاد	(0.09')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-10851.88	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.003	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.007	mm	
Displacement of bearing	[ur]	0.007	mm	(66.26°)
Misalignment of bearing	[rx]	0.022	mrاد	(0.08')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	-0.010	mrاد	(-0.03')

Misalignment of bearing [rr] 0.024 mrad (0.08')

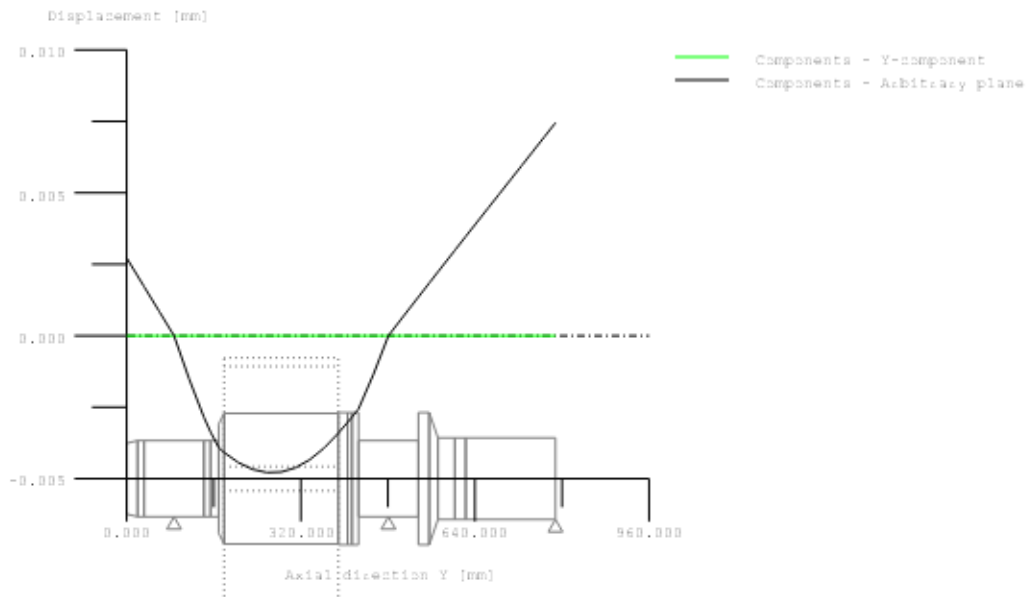
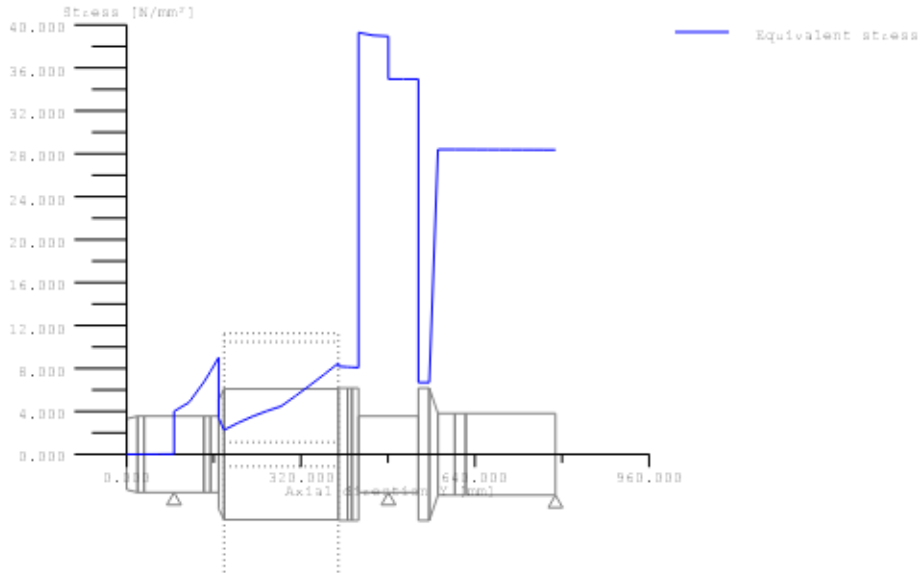


Figure: Displacement (bending etc.) (Arbitrary plane 66.25583028 °)



$$\text{GEH(von Mises): } \sigma_V = \left((\sigma_B + \sigma_Z, D)^2 + 3 * (\tau_T + \tau_S)^2 \right)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.80	22.51	29.48
3	3.32	0.87	0.80	4.50	6.72
2	3.32	0.87	0.80	4.05	6.66

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

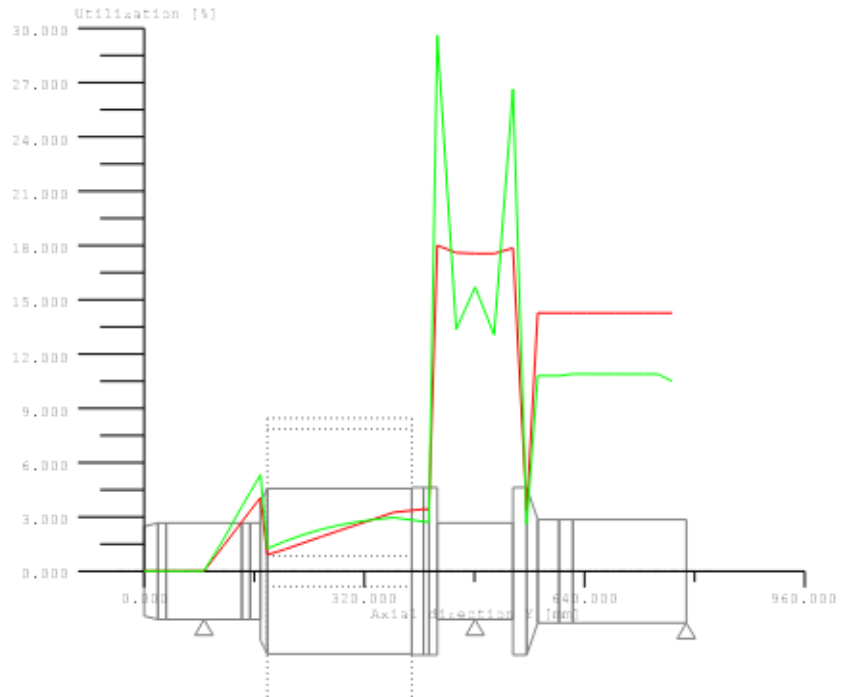


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 449.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 250.00
 Material data calculated according DIN743/3 with K1(d)
 Material strength calculated from size of raw material
 Geometric size coefficient K1d calculated from raw material diameter
 [sigBeff] (N/mm²) 482.72
 [sigSeff] (N/mm²) 337.91
 [sigbF] (N/mm²) 405.49
 [tautF] (N/mm²) 234.11
 [sigzdW] (N/mm²) 193.09
 [sigbW] (N/mm²) 241.36
 [tautW] (N/mm²) 144.82

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (μm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	2180.0	0.0	26600.3
Maximum value	0.0	3705.9	0.0	45220.5
Cross section, moment of resistance: (mm^2)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm^2)				
[sigzdm, sigbm, taum, tauqm] (N/mm^2)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm^2)	0.000	8.092	0.000	2.304
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm^2)	0.000	13.757	0.000	3.917

Technological size influence	[K1 (sigB)]	0.690
	[K1 (sigS)]	0.690

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.924	0.956
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.082	1.289

Present margin of safety for endurance limit:			
Equivalent mean stress (N/mm^2)	[sigmV]	0.000	
Equivalent mean stress (N/mm^2)	[taumV]	0.000	
Fatigue limit of part (N/mm^2)	[sigWK]	178.410	182.143
Influence coeff. mean stress sensitivity.			
	[PsisigK]	0.227	0.233
Permissible amplitude (N/mm^2)	[sigADK]	178.410	182.143
Margin of safety endurance limit	[S]		22.508
Required safety	[Smin]		1.200
Result (%)	[S/Smin]		1875.7

Present margin of safety for proof against exceed of yield point:			
Static notch sensitivity factor	[K2F]	1.000	1.200
Increase coefficient	[gammaF]	1.000	1.000
Yield stress of part (N/mm^2)	[sigFK]	337.907	405.489
Margin of safety yield stress	[S]		29.476
Required safety	[Smin]		1.200
Result (%)	[S/Smin]		2456.3

Cross section '3' Shoulder with relief groove

Comment				
Position (Y-Coordinate) (mm)	[y]	536.00		
External diameter (mm)	[da]	140.000		
Inner diameter (mm)	[di]	0.000		
Notch effect Shoulder with relief groove				
[D, d, D1, r, t] (mm)		243.00	139.20	140.00
Shape B				1.20
Mean roughness (μm)	[Rz]			32.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	5425.9	0.0
Amplitude	0.0	43.9	5425.9	420.0
Maximum value	-0.0	74.6	18448.2	714.0
Cross section, moment of resistance: (mm^2)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm^2)				
[sigzdm, sigbm, taum, tauqm] (N/mm^2)	-0.000	0.000	10.245	0.000
[sigzda, sigba, taua, tauqa] (N/mm^2)	0.000	0.166	10.245	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm^2)	-0.000	0.282	34.834	0.063

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	17.745		
Equivalent mean stress (N/mm ²)	[taumV]	10.245		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.022	4.317	46.858
Margin of safety endurance limit	[S]		4.505	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		375.4	
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		6.721	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		560.1	

Cross section '2' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]		426.00		
External diameter (mm)	[da]		140.000		
Inner diameter (mm)	[di]		0.000		
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]		32.000		
				Tension/Compression	Bending Torsion Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	5425.9	0.0
Amplitude		0.0	1421.7	5425.9	26944.0
Maximum value		-0.0	2416.9	18448.2	45804.8
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4
Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	10.245	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	5.369	10.245	2.361
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	9.127	34.834	4.013

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	17.745		
Equivalent mean stress (N/mm ²)	[taumV]	10.245		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.022	46.915	46.858
Margin of safety endurance limit	[S]		4.052	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		337.7	

Present margin of safety
 for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		6.663	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		555.3	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
 The reference diameter for the notch number is not defined.
 Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
 The notching factor for the light fit case is no longer defined in DIN 743.
 The values are imported from the FKM-Guideline..

End report

lines: 531

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z4
Changed by : jirisuch on: 14.03.2014 at: 17:42:17

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	2568.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	81.425
Mass moment of inertia (kg*m ²)	0.210
Momentum of mass GD2 (Nm ²)	8.258
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

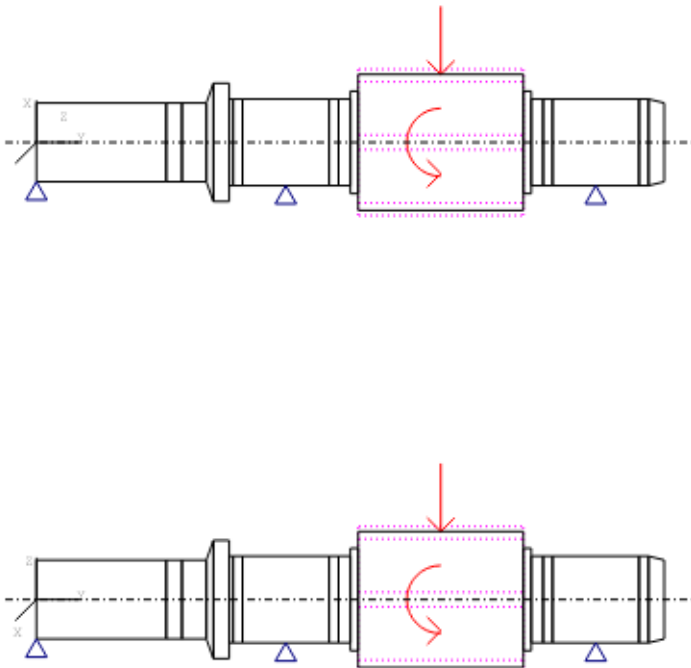


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z4 nahrada) d=172.70 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z4 i34)			y= 514.00 (mm)
Operating pitch diameter	(mm)	185.6842	
Helix angle	(°)	25.0375	Double helical gearing, left-right
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	1897.3882	
Axial force	(N)	0.0000	
Shearing force X	(N)	-8307.7637	
Shearing force Z	(N)	-20436.7214	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 13.37 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 433.5 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.05 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm	
Bearing reaction force	[Fx]	4.154	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	10.771	kN	
Bearing reaction force	[Fr]	11.544	kN	(68.91°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.041	mrاد	(-0.14')
Misalignment of bearing	[ry]	0.665	mrاد	(2.29')
Misalignment of bearing	[rz]	0.017	mrاد	(0.06')
Misalignment of bearing	[rr]	0.044	mrاد	(0.15')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm	
Bearing reaction force	[Fx]	4.154	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	10.465	kN	
Bearing reaction force	[Fr]	11.259	kN	(68.35°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.042	mrاد	(0.14')
Misalignment of bearing	[ry]	0.839	mrاد	(2.88')
Misalignment of bearing	[rz]	-0.017	mrاد	(-0.06')
Misalignment of bearing	[rr]	0.045	mrاد	(0.15')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	0.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-1897.39	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.005	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.012	mm	
Displacement of bearing	[ur]	0.013	mm	(66.46°)
Misalignment of bearing	[rx]	-0.038	mrاد	(-0.13')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.017	mrاد	(0.06')
Misalignment of bearing	[rr]	0.042	mrاد	(0.14')

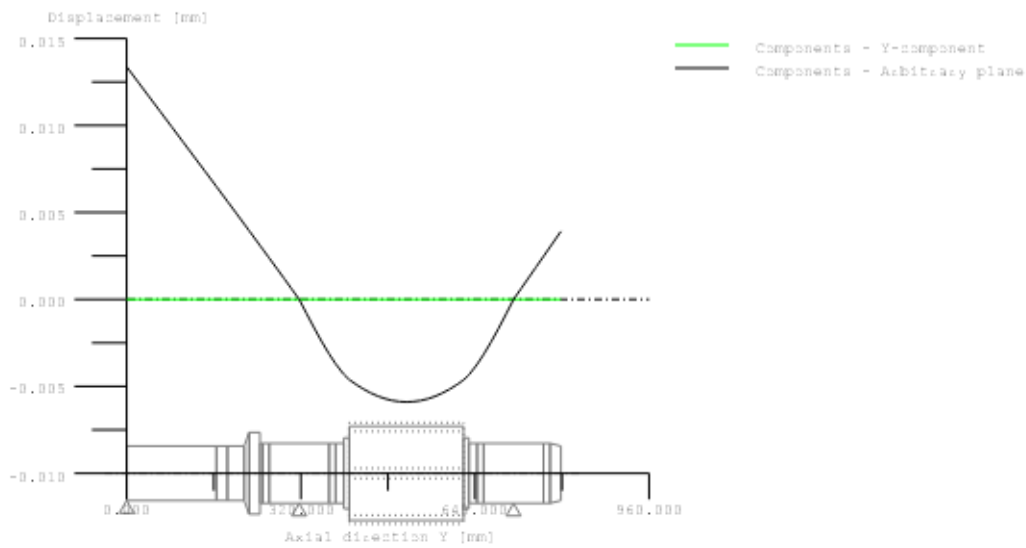
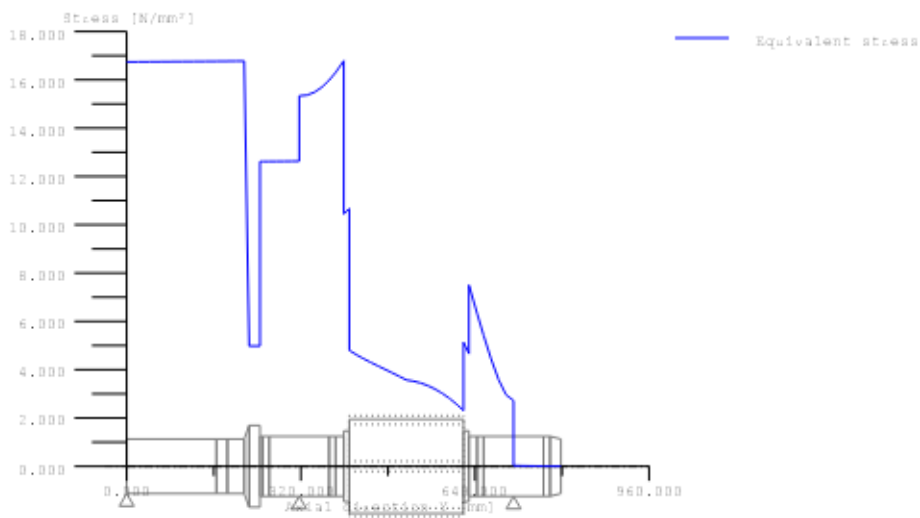


Figure: Displacement (bending etc.) (Arbitrary plane 66.46142499 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress

End report

lines: 220

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z44
Changed by : jirisuch on: 14.03.2014 at: 17:43:19

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	1073.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	81.425
Mass moment of inertia (kg*m ²)	0.210
Momentum of mass GD2 (Nm ²)	8.258
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

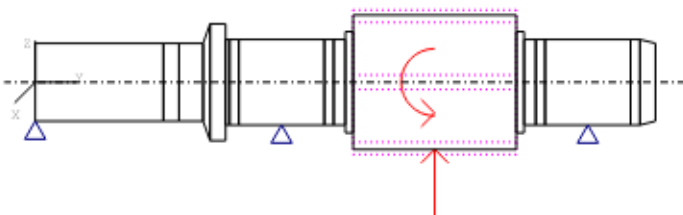
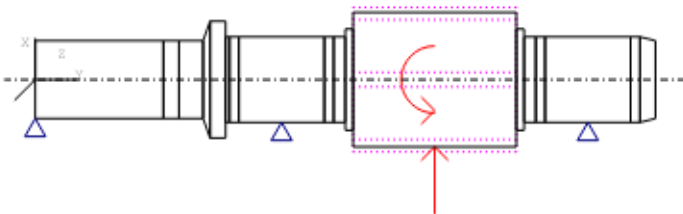


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z4 nahrada) d=172.70 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z4 i43)			y= 514.00 (mm)
Operating pitch diameter	(mm)	185.6842	
Helix angle	(°)	25.0375	Double helical gearing, left-right
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	4541.0000	
Axial force	(N)	0.0000	
Shearing force X	(N)	19882.8865	
Shearing force Z	(N)	48910.9977	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 34.75 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 433.5 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.12 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm
Bearing reaction force	[Fx]	-9.941	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-23.903	kN
Bearing reaction force	[Fr]	25.888	kN (-112.58°)
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	0.100	mrاد (0.34')
Misalignment of bearing	[ry]	1.592	mrاد (5.47')
Misalignment of bearing	[rz]	-0.040	mrاد (-0.14')
Misalignment of bearing	[rr]	0.108	mrاد (0.37')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm
Bearing reaction force	[Fx]	-9.941	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-24.209	kN
Bearing reaction force	[Fr]	26.171	kN (-112.33°)
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	-0.099	mrاد (-0.34')
Misalignment of bearing	[ry]	2.008	mrاد (6.9')
Misalignment of bearing	[rz]	0.040	mrاد (0.14')
Misalignment of bearing	[rr]	0.107	mrاد (0.37')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	0.00	mm
Bearing reaction force	[Fx]	0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	0.000	kN
Bearing reaction force	[Fr]	0.000	kN
Bearing reaction moment	[Mx]	0.00	Nm
Bearing reaction moment	[My]	-4541.00	Nm
Bearing reaction moment	[Mz]	0.00	Nm
Bearing reaction moment	[Mr]	0.00	Nm (0°)
Displacement of bearing	[ux]	-0.013	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	-0.032	mm
Displacement of bearing	[ur]	0.035	mm (-111.58°)
Misalignment of bearing	[rx]	0.102	mrاد (0.35')
Misalignment of bearing	[ry]	0.000	mrاد (0')
Misalignment of bearing	[rz]	-0.040	mrاد (-0.14')
Misalignment of bearing	[rr]	0.110	mrاد (0.38')

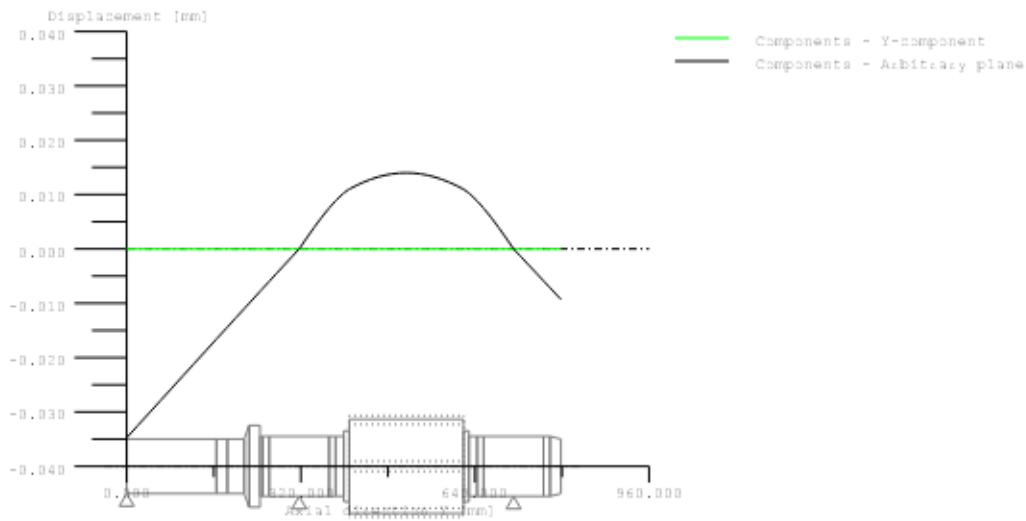
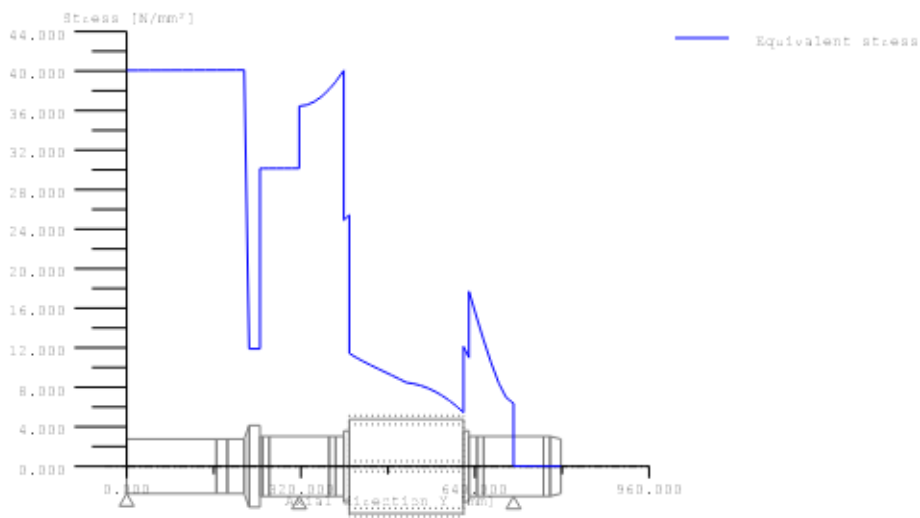
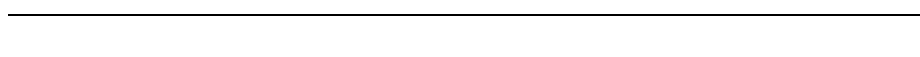


Figure: Displacement (bending etc.) (Arbitrary plane 68.42257063 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress



**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	245.10	Smooth shaft
2	317.00	Smooth shaft
3	399.00	Own Input
4	629.00	Own Input
5	655.00	Smooth shaft
6	766.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.82	11.21	8.35
2	1.00	0.92	0.82	11.20	8.35
3	1.00	0.92	0.82	7.57	7.31
4	1.00	0.92	0.82	11.81	15.24
5	1.00	0.92	0.82	17.28	22.31
6	1.00	0.92	0.82	10000.00	10000.00

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

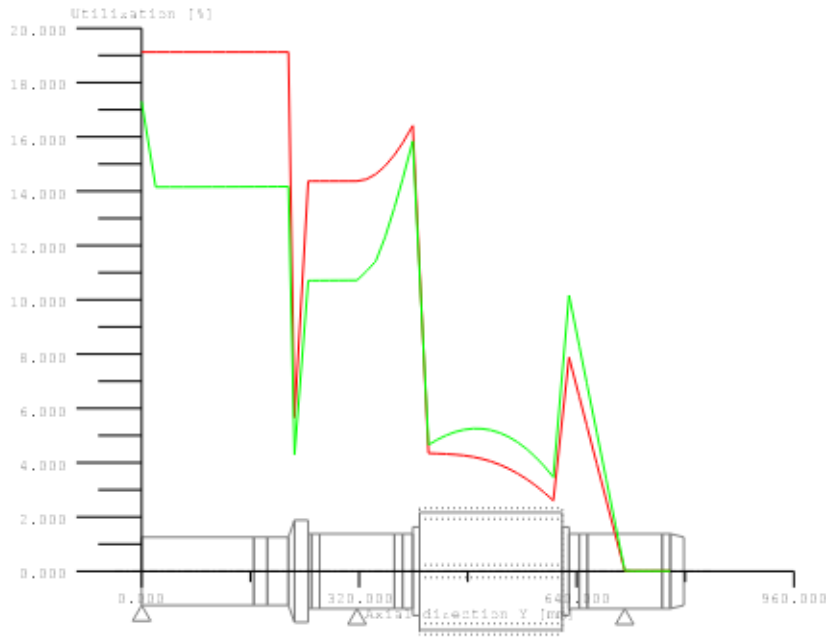


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 798.00
 Speed (1/min) [n] 1073.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 180.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 508.69
 [sigSeff] (N/mm²) 356.08
 [sigbF] (N/mm²) 427.30
 [tautF] (N/mm²) 246.70
 [sigzdW] (N/mm²) 203.48
 [sigbW] (N/mm²) 254.35
 [tautW] (N/mm²) 152.61

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	245.10
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	18.3	2270.5	166.3
Maximum value	-0.0	31.2	7719.7	282.7
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.140	8.688	0.023
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.239	29.539	0.040

Technological size influence	[K1 (sigB)]	0.727
	[K1 (sigS)]	0.727

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821
Influence coefficient surface roughness	[KF]	0.919	0.919
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.088	1.306

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	187.086	194.741	120.445
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.225	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.024	3.950	106.186
Margin of safety endurance limit	[S]		11.210	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		934.2	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	356.083	427.300	246.702
Margin of safety yield stress	[S]		8.352	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		696.0	

Cross section '2' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	317.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	32.2	2270.5	213.8
Maximum value	-0.0	54.7	7719.7	363.4
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.246	8.688	0.030
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.419	29.539	0.051

Technological size influence	[K1 (sigB)]	0.727
	[K1 (sigS)]	0.727

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.919	0.919	0.954
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.088	1.306	1.267

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	187.086	194.741	120.445
Influence coeff. mean stress sensitivity.	[PsisigK]	0.225	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.024	6.881	106.186
Margin of safety endurance limit	[S]		11.198	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		933.1	

Present margin of safety for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	356.083	427.300	246.702
Margin of safety yield stress	[S]		8.352	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		696.0	

Cross section '3' Own Input

Comment		
Position (Y-Coordinate) (mm)	[y]	399.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Own Input		
Mean roughness (µm)	[Rz]	8.000

		Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	2171.4	2270.5	26140.2
Maximum value		-0.0	3691.4	7719.7	44438.3
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		9503.3	130671	261341	9503.3

Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	16.618	8.688	3.668
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	28.250	29.539	6.235

Technological size influence	[K1 (sigB)]	0.727
	[K1 (sigS)]	0.727

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.919	0.919	0.954
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.088	1.306	1.267

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	187.086	194.741	120.445
Influence coeff. mean stress sensitivity.	[PsisigK]	0.225	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.024	160.365	106.186
Margin of safety endurance limit	[S]		7.574	

Required safety	[Smin]	1.200		
Result (%)	[S/Smin]	631.2		
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	356.083	427.300	246.702
Margin of safety yield stress	[S]		7.311	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		609.3	

Cross section '4' Own Input

Comment				
Position (Y-Coordinate) (mm)	[y]		629.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Own Input				
Mean roughness (µm)	[Rz]		8.000	
Tension/Compression Bending Torsion Shearing				
Stress: (N) (Nm)				
Mean value		-0.0	0.0	0.0 0.0
Amplitude		0.0	2155.5	0.0 26288.7
Maximum value		-0.0	3664.3	0.0 44690.8
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]		9503.3	130671	261341 9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	0.000 0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	16.495	0.000 3.688
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	28.042	0.000 6.270

Technological size influence	[K1(sigB)]		0.727	
	[K1(sigS)]		0.727	

Tension/Compression Bending Torsion				
Notch effect coefficient	[beta(dB)]	0.000	0.000	0.000
[dB] (mm) = 0.0				
Geometrical size influence	[K3(d)]	0.000	0.000	0.000
Geometrical size influence	[K3(dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.919	0.919	0.954
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.088	1.306	1.267

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	187.086	194.741	120.445
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.225	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	187.086	194.741	120.445
Margin of safety endurance limit	[S]		11.806	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		983.8	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	356.083	427.300	246.702
Margin of safety yield stress	[S]		15.238	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1269.8	

Cross section '5' Smooth shaft

Comment				
Position (Y-Coordinate) (mm)	[y]		655.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Smooth shaft				
Mean roughness (µm)	[Rz]		8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	1472.3	0.0	26270.1
Maximum value	-0.0	2502.9	0.0	44659.2
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	11.267	0.000	3.686
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	19.155	0.000	6.266

Technological size influence	[K1 (sigB)]	0.727
	[K1 (sigS)]	0.727

		Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000	0.000
[dB] (mm) =	0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.919	0.919	0.954
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.088	1.306	1.267

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	0.000		
Equivalent mean stress (N/mm ²)	[taumV]	0.000		
Fatigue limit of part (N/mm ²)	[sigWK]	187.086	194.741	120.445
Influence coeff. mean stress sensitivity.	[PsigK]	0.225	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	187.086	194.741	120.445
Margin of safety endurance limit	[S]		17.284	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1440.3	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	356.083	427.300	246.702
Margin of safety yield stress	[S]		22.308	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1859.0	

Cross section '6' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	766.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	0.3	0.0	27.1
Maximum value	-0.0	0.6	0.0	46.1
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.003	0.000	0.004
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.004	0.000	0.006

Technological size influence	[K1 (sigB)]	0.727
	[K1 (sigS)]	0.727

		Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000	0.000
[dB] (mm) =	0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000

Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.919	0.919	0.954
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.088	1.306	1.267

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	187.086	194.741	120.445
Influence coeff. mean stress sensitivity.	[PsigK]	0.225	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	187.086	194.741	120.445
Margin of safety endurance limit	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety

for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	356.083	427.300	246.702
Margin of safety yield stress	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
The reference diameter for the notch number is not defined.
Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
The notching factor for the light fit case is no longer defined in DIN 743.
The values are imported from the FKM-Guideline..

End report

lines: 710

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z5
Changed by : jirisuch on: 14.03.2014 at: 17:44:20

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	1073.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	165.288
Mass moment of inertia (kg*m ²)	0.898
Momentum of mass GD2 (Nm ²)	35.218
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

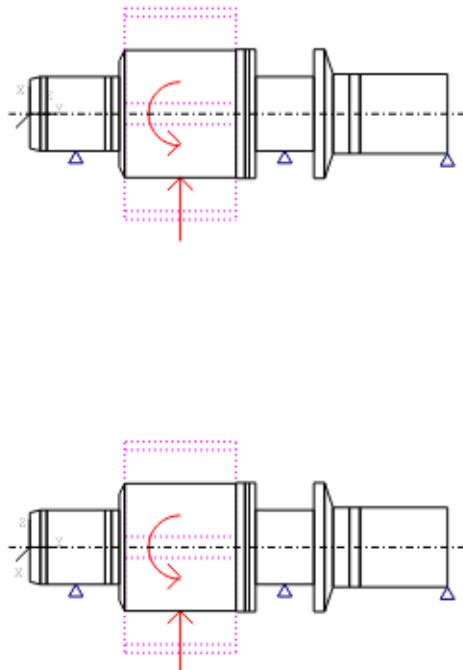


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone)	y= 0.00...20.00 (mm)
dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 20.00...32.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 32.00...142.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 1.8	
Cylinder (Cylinder)	y= 142.00...154.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 154.00...169.00 (mm)
d=140.00 (mm), l=15.00 (mm), Rz= 8.0	
Taper (Cone)	y= 169.00...179.00 (mm)
dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	
Cylinder (z5 nahrada)	y= 179.00...389.00 (mm)
d=240.00 (mm), l=210.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 389.00...406.00 (mm)
d=243.00 (mm), l=17.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 406.00...414.00 (mm)
d=243.00 (mm), l=8.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 414.00...426.00 (mm)
d=243.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 426.00...536.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 2.8	
Relief groove left (Relief groove left)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder)	y= 536.00...556.00 (mm)
d=243.00 (mm), l=20.00 (mm), Rz=32.0	
Taper (Cone)	y= 556.00...572.00 (mm)
dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 572.00...603.00 (mm)
d=150.00 (mm), l=31.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 603.00...623.00 (mm)
d=150.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 623.00...788.00 (mm)
d=150.00 (mm), l=165.00 (mm), Rz=16.0	

Inner contour

Forces

Cylindrical gear (z5 i56)	y= 284.00 (mm)		
Operating pitch diameter	(mm)	397.8947	
Helix angle	(°)	25.0375	Double helical gearing, right-left
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driving (Output)
Torque	(Nm)	4541.0000	
Axial force	(N)	0.0000	
Shearing force X	(N)	9278.6804	
Shearing force Z	(N)	22825.1323	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 4.25 μ m (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 371.1 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.03 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	-4.639	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-10.969	kN	
Bearing reaction force	[Fr]	11.910	kN	(-112.93°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.013	mrاد	(0.05')
Misalignment of bearing	[ry]	0.450	mrاد	(1.55')
Misalignment of bearing	[rz]	-0.005	mrاد	(-0.02')
Misalignment of bearing	[rr]	0.014	mrاد	(0.05')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	-4.639	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-10.233	kN	
Bearing reaction force	[Fr]	11.236	kN	(-114.39°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.012	mrاد	(-0.04')
Misalignment of bearing	[ry]	0.342	mrاد	(1.18')
Misalignment of bearing	[rz]	0.005	mrاد	(0.02')
Misalignment of bearing	[rr]	0.013	mrاد	(0.04')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-4541.00	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	-0.001	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.004	mm	
Displacement of bearing	[ur]	0.004	mm	(-109.28°)
Misalignment of bearing	[rx]	-0.013	mrاد	(-0.05')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.005	mrاد	(0.02')

Misalignment of bearing [rr] 0.014 mrad (0.05')

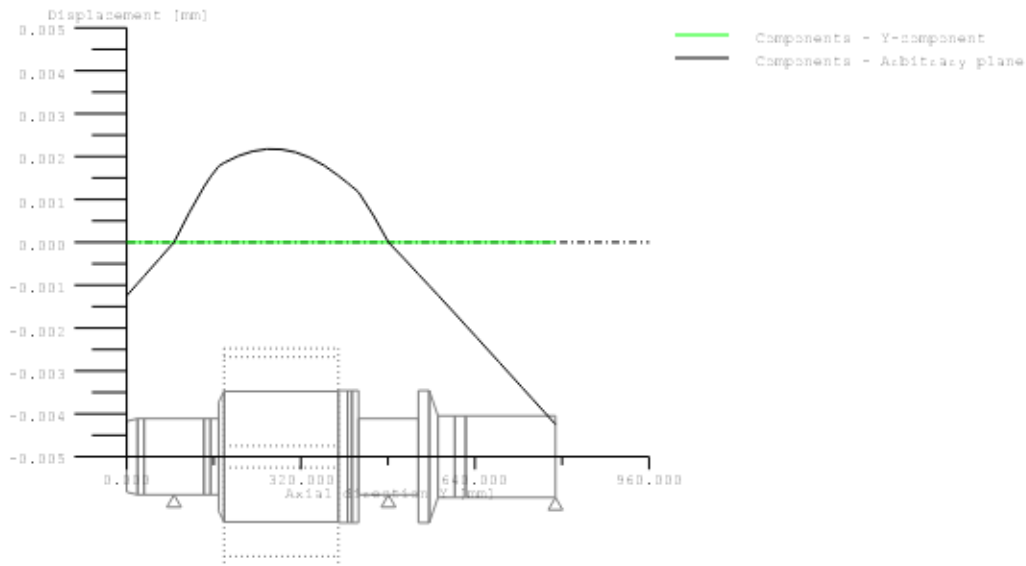
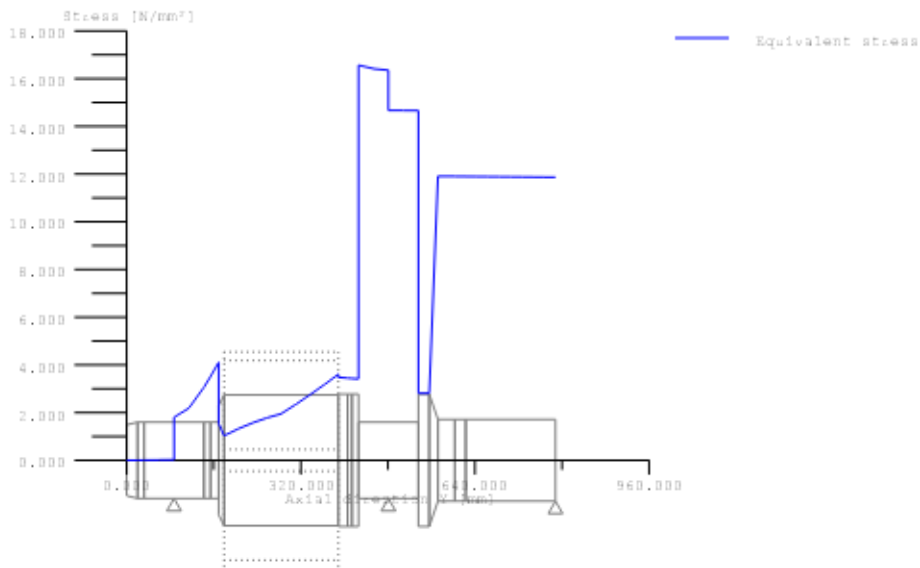


Figure: Displacement (bending etc.) (Arbitrary plane 70.72411585 °)



$$\text{GEH(von Mises): } \sigma_V = \left((\sigma_B + \sigma_Z, D)^2 + 3 \cdot (\tau_T + \tau_S)^2 \right)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.80	49.47	64.79
3	3.32	0.87	0.80	10.76	16.06
2	3.32	0.87	0.80	9.35	15.87

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

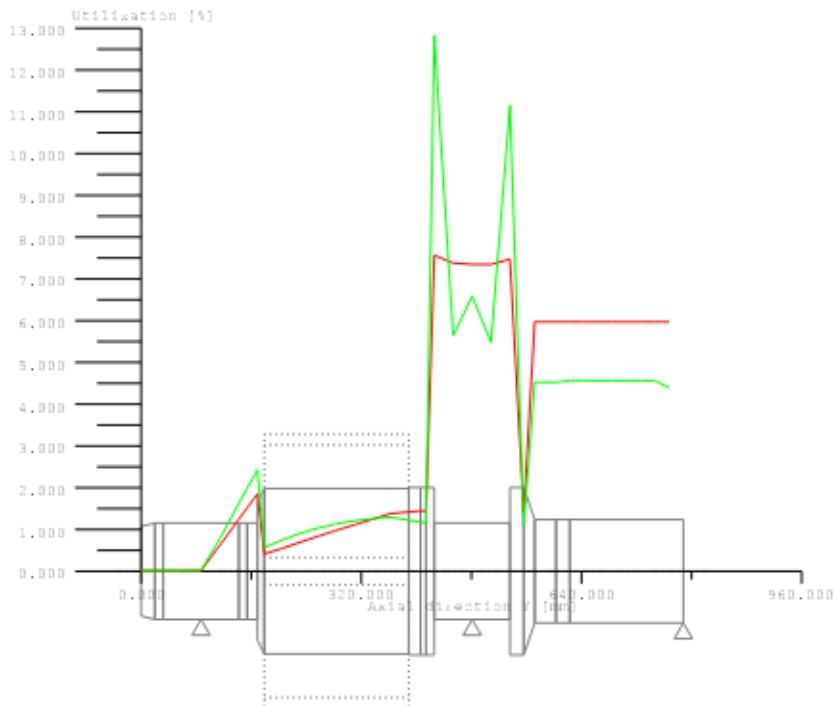


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 1073.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 250.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 482.72
 [sigSeff] (N/mm²) 337.91
 [sigbF] (N/mm²) 405.49
 [tautF] (N/mm²) 234.11
 [sigzdW] (N/mm²) 193.09
 [sigbW] (N/mm²) 241.36
 [tautW] (N/mm²) 144.82

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	991.8	0.0	12084.5
Maximum value	0.0	1686.1	0.0	20543.6
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	3.682	0.000	1.047
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	0.000	6.259	0.000	1.779

Technological size influence	[K1 (sigB)]	0.690
	[K1 (sigS)]	0.690

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.924	0.956
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.082	1.325

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	0.000		
Equivalent mean stress (N/mm ²)	[taumV]	0.000		
Fatigue limit of part (N/mm ²)	[sigWK]	178.410	182.143	112.387
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.227	0.233	0.132
Permissible amplitude (N/mm ²)	[sigADK]	178.410	182.143	112.387
Margin of safety endurance limit	[S]		49.474	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		4122.8	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	337.907	405.489	234.109
Margin of safety yield stress	[S]		64.788	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		5399.0	

Cross section '3' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]	536.00			
External diameter (mm)	[da]	140.000			
Inner diameter (mm)	[di]	0.000			
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]				32.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	43.9	2270.5	420.0
Maximum value	-0.0	74.6	7719.7	714.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.166	4.287	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.282	14.576	0.063

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.052	10.185	46.858
Margin of safety endurance limit	[S]		10.761	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		896.7	
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		16.060	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1338.3	

Cross section '2' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]		426.00		
External diameter (mm)	[da]		140.000		
Inner diameter (mm)	[di]		0.000		
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]		32.000		
				Tension/Compression	Bending Torsion Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	706.0	2270.5	11743.6
Maximum value		-0.0	1200.3	7719.7	19964.1
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4
Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	2.666	4.287	1.029
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	4.533	14.576	1.749

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.052	48.210	46.858
Margin of safety endurance limit	[S]		9.354	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		779.5	

Present margin of safety
 for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		15.869	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1322.4	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
 The reference diameter for the notch number is not defined.
 Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
 The notching factor for the light fit case is no longer defined in DIN 743.
 The values are imported from the FKM-Guideline..

End report

lines: 531

_____ KISSsoft - Release 03-2012F _____
KISSsoft academic license for Uni Pilsen

_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z55
Changed by : jirisuch on: 14.03.2014 at: 17:45:36

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	626.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	165.288
Mass moment of inertia (kg*m ²)	0.898
Momentum of mass GD2 (Nm ²)	35.218
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

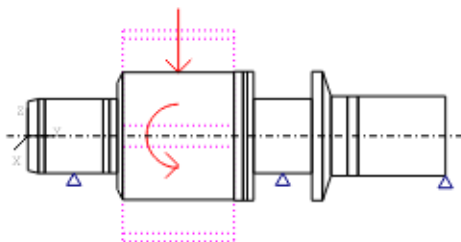
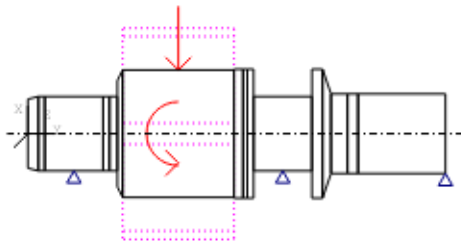


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone)	y= 0.00...20.00 (mm)
dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 20.00...32.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 32.00...142.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 1.8	
Cylinder (Cylinder)	y= 142.00...154.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 154.00...169.00 (mm)
d=140.00 (mm), l=15.00 (mm), Rz= 8.0	
Taper (Cone)	y= 169.00...179.00 (mm)
dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	
Cylinder (z5 nahrada)	y= 179.00...389.00 (mm)
d=240.00 (mm), l=210.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 389.00...406.00 (mm)
d=243.00 (mm), l=17.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 406.00...414.00 (mm)
d=243.00 (mm), l=8.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 414.00...426.00 (mm)
d=243.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 426.00...536.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 2.8	
Relief groove left (Relief groove left)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder)	y= 536.00...556.00 (mm)
d=243.00 (mm), l=20.00 (mm), Rz=32.0	
Taper (Cone)	y= 556.00...572.00 (mm)
dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 572.00...603.00 (mm)
d=150.00 (mm), l=31.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 603.00...623.00 (mm)
d=150.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 623.00...788.00 (mm)
d=150.00 (mm), l=165.00 (mm), Rz=16.0	

Inner contour

Forces

Cylindrical gear (z5 i65)	y= 284.00 (mm)		
Operating pitch diameter	(mm)	397.8947	
Helix angle	(°)	25.0375	Double helical gearing, right-left
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driving (Output)
Torque	(Nm)	7783.5351	
Axial force	(N)	0.0000	
Shearing force X	(N)	-15904.1917	
Shearing force Z	(N)	-39123.5893	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 5.86 µm (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 371.1 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.04 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	7.952	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	20.005	kN	
Bearing reaction force	[Fr]	21.528	kN	(68.32°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.023	mrاد	(-0.08')
Misalignment of bearing	[ry]	0.772	mrاد	(2.65')
Misalignment of bearing	[rz]	0.009	mrاد	(0.03')
Misalignment of bearing	[rr]	0.025	mrاد	(0.09')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	7.952	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	20.741	kN	
Bearing reaction force	[Fr]	22.213	kN	(69.02°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.019	mrاد	(0.06')
Misalignment of bearing	[ry]	0.586	mrاد	(2.02')
Misalignment of bearing	[rz]	-0.008	mrاد	(-0.03')
Misalignment of bearing	[rr]	0.020	mrاد	(0.07')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-7783.54	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.002	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.005	mm	
Displacement of bearing	[ur]	0.006	mm	(65.82°)
Misalignment of bearing	[rx]	0.017	mrاد	(0.06')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	-0.008	mrاد	(-0.03')

Misalignment of bearing [rr] 0.019 mrad (0.07')

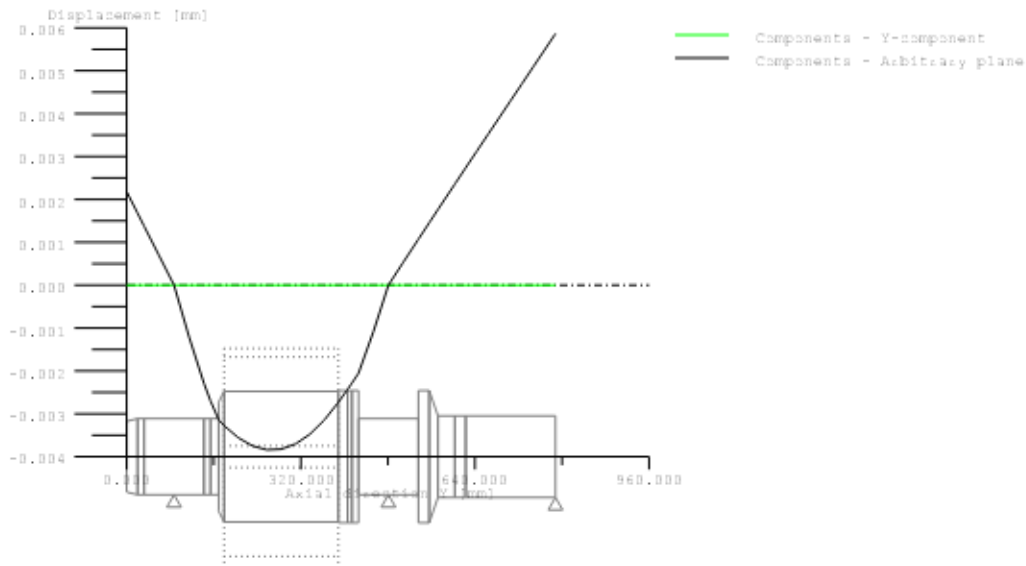
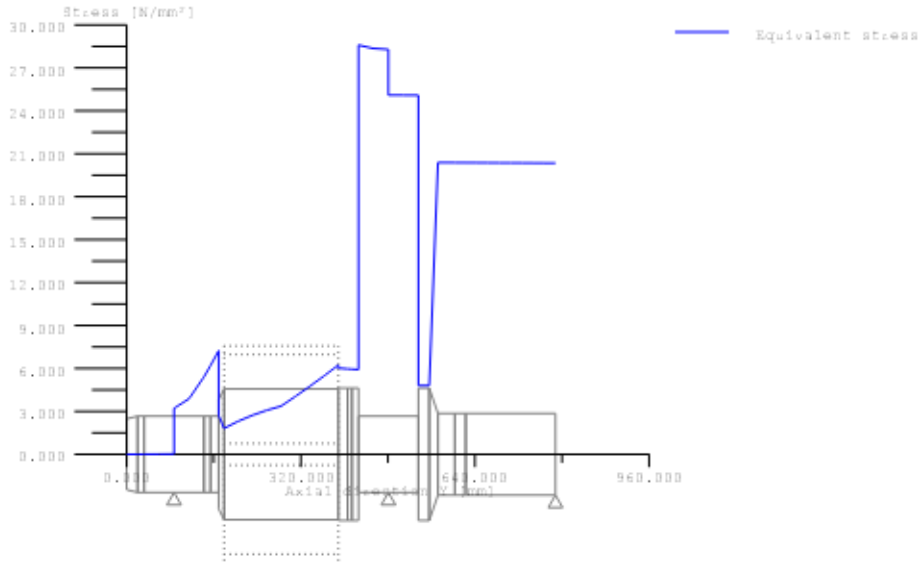


Figure: Displacement (bending etc.) (Arbitrary plane 65.81738906 °)



$$GEH(\text{von Mises}): \sigma_V = ((\sigma_B + \sigma_Z, D)^2 + 3 * (\tau_T + \tau_S)^2)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
 DIN 743:2000**

Summary

Label Shaft 1
 Drawing

Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

Calculation of endurance limit and the static strength
 Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.80	28.04	36.73
3	3.32	0.87	0.80	6.28	9.37
2	3.32	0.87	0.80	5.54	9.27

Nominal safety: 1.20 1.20

Abbreviations:
 Kfb: Notch factor bending
 Kfsig: Surface factor
 K2d: Size coefficient bending
 SD: Safety endurance limit
 SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

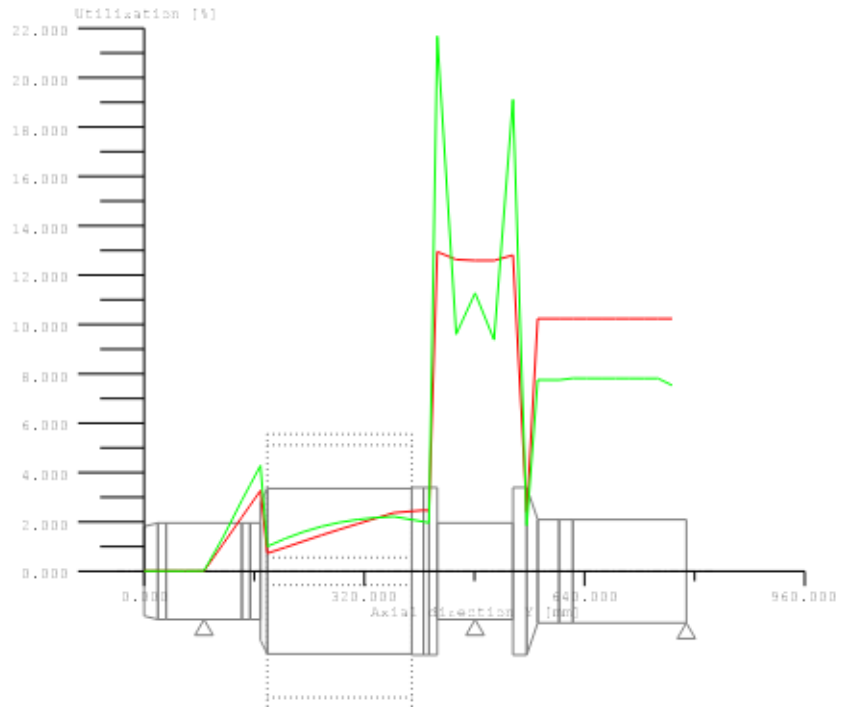


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 626.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 250.00
 Material data calculated according DIN743/3 with K1(d)
 Material strength calculated from size of raw material
 Geometric size coefficient K1d calculated from raw material diameter
 [sigBeff] (N/mm²) 482.72
 [sigSeff] (N/mm²) 337.91
 [sigbF] (N/mm²) 405.49
 [tautF] (N/mm²) 234.11
 [sigzdW] (N/mm²) 193.09
 [sigbW] (N/mm²) 241.36
 [tautW] (N/mm²) 144.82

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	1749.7	0.0	21352.0
Maximum value	0.0	2974.4	0.0	36298.3
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	6.495	0.000	1.849
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	0.000	11.041	0.000	3.144

Technological size influence	[K1 (sigB)]	0.690
	[K1 (sigS)]	0.690

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) =	0.0		
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.924	0.956
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.082	1.289

Present margin of safety for endurance limit:			
Equivalent mean stress (N/mm ²)	[sigmV]	0.000	
Equivalent mean stress (N/mm ²)	[taumV]	0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	178.410	182.143
Influence coeff. mean stress sensitivity.			
	[PsisigK]	0.227	0.233
Permissible amplitude (N/mm ²)	[sigADK]	178.410	182.143
Margin of safety endurance limit	[S]		28.044
Required safety	[Smin]		1.200
Result (%)	[S/Smin]		2337.0

Present margin of safety for proof against exceed of yield point:			
Static notch sensitivity factor	[K2F]	1.000	1.200
Increase coefficient	[gammaF]	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	337.907	405.489
Margin of safety yield stress	[S]		36.725
Required safety	[Smin]		1.200
Result (%)	[S/Smin]		3060.4

Cross section '3' Shoulder with relief groove

Comment				
Position (Y-Coordinate) (mm)	[y]	536.00		
External diameter (mm)	[da]	140.000		
Inner diameter (mm)	[di]	0.000		
Notch effect Shoulder with relief groove				
[D, d, D1, r, t] (mm)		243.00	139.20	140.00
Shape B				1.20
Mean roughness (µm)	[Rz]			32.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	3891.8	0.0
Amplitude	0.0	43.9	3891.8	420.0
Maximum value	-0.0	74.6	13232.0	714.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	7.349	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.166	7.349	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.282	24.985	0.063

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	12.728		
Equivalent mean stress (N/mm ²)	[taumV]	7.349		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.031	5.997	46.858
Margin of safety endurance limit	[S]		6.280	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		523.3	
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		9.370	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		780.8	

Cross section '2' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]		426.00		
External diameter (mm)	[da]		140.000		
Inner diameter (mm)	[di]		0.000		
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]			32.000	
			Tension/Compression	Bending Torsion	Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	3891.8	0.0
Amplitude		0.0	1133.1	3891.8	21695.9
Maximum value		-0.0	1926.2	13232.0	36883.0
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4
Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	7.349	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	4.279	7.349	1.901
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	7.274	24.985	3.231

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	12.728		
Equivalent mean stress (N/mm ²)	[taumV]	7.349		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.031	47.730	46.858
Margin of safety endurance limit	[S]		5.536	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		461.3	

Present margin of safety
for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		9.271	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		772.6	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
The reference diameter for the notch number is not defined.
Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
The notching factor for the light fit case is no longer defined in DIN 743.
The values are imported from the FKM-Guideline..

End report

lines: 531

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z6
Changed by : jirisuch on: 14.03.2014 at: 17:46:03

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	1840.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	104.446
Mass moment of inertia (kg*m ²)	0.433
Momentum of mass GD2 (Nm ²)	17.007
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

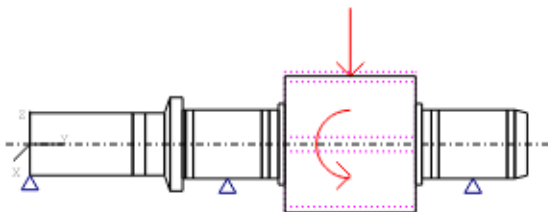
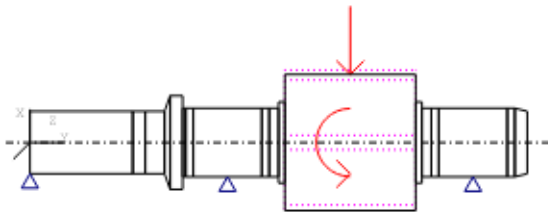


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z6 nahrada) d=218.29 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z6 i56)			y= 514.00 (mm)
Operating pitch diameter	(mm)	232.1053	
Helix angle	(°)	25.0375	Double helical gearing, left-right
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	2648.0940	
Axial force	(N)	0.0000	
Shearing force X	(N)	-9275.7988	
Shearing force Z	(N)	-22818.0437	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 11.59 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 451.3 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.07 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm	
Bearing reaction force	[Fx]	4.638	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	12.075	kN	
Bearing reaction force	[Fr]	12.935	kN	(68.99°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.035	mrاد	(-0.12')
Misalignment of bearing	[ry]	0.928	mrاد	(3.19')
Misalignment of bearing	[rz]	0.015	mrاد	(0.05')
Misalignment of bearing	[rr]	0.038	mrاد	(0.13')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm	
Bearing reaction force	[Fx]	4.638	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	11.768	kN	
Bearing reaction force	[Fr]	12.649	kN	(68.49°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.037	mrاد	(0.13')
Misalignment of bearing	[ry]	1.147	mrاد	(3.94')
Misalignment of bearing	[rz]	-0.015	mrاد	(-0.05')
Misalignment of bearing	[rr]	0.039	mrاد	(0.14')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	0.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-2648.09	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.005	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.011	mm	
Displacement of bearing	[ur]	0.012	mm	(66.42°)
Misalignment of bearing	[rx]	-0.033	mrاد	(-0.11')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.015	mrاد	(0.05')
Misalignment of bearing	[rr]	0.036	mrاد	(0.12')

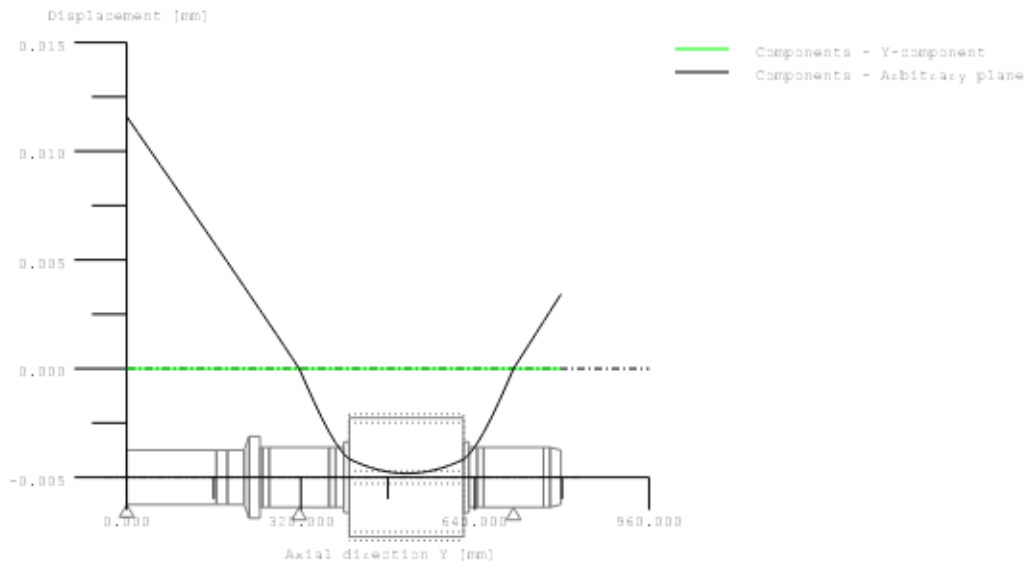
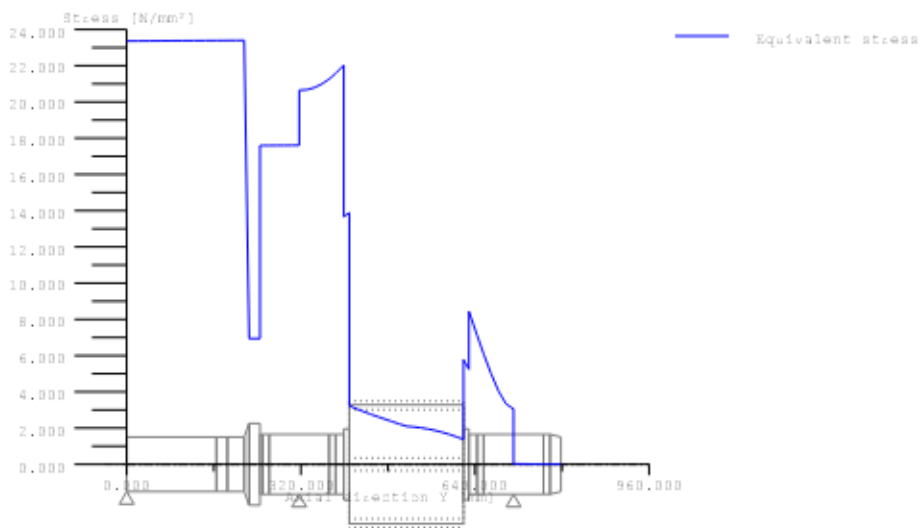
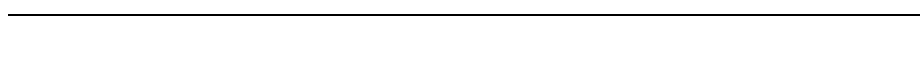


Figure: Displacement (bending etc.) (Arbitrary plane 66.42364171 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress



End report

lines: 220

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_____ File _____
Name : hridel_z66
Changed by : jirisuch on: 14.03.2014 at: 17:48:35

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	1073.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	104.446
Mass moment of inertia (kg*m ²)	0.433
Momentum of mass GD2 (Nm ²)	17.007
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

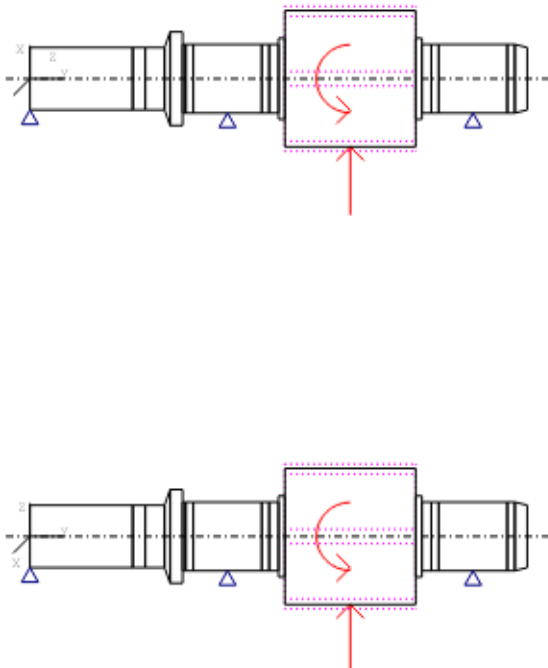


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z6 nahrada) d=218.29 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z6 i65)			y= 514.00 (mm)
Operating pitch diameter	(mm)	232.1053	
Helix angle	(°)	25.0375	Double helical gearing, left-right
Working pressure angle at normal section(°)		20.2194	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	4541.0000	
Axial force	(N)	0.0000	
Shearing force X	(N)	15906.3092	
Shearing force Z	(N)	39128.7982	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 21.83 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 451.3 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.11 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm	
Bearing reaction force	[Fx]	-7.953	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-18.899	kN	
Bearing reaction force	[Fr]	20.504	kN	(-112.82°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.062	mrاد	(0.21')
Misalignment of bearing	[ry]	1.592	mrاد	(5.47')
Misalignment of bearing	[rz]	-0.025	mrاد	(-0.09')
Misalignment of bearing	[rr]	0.067	mrاد	(0.23')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm	
Bearing reaction force	[Fx]	-7.953	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-19.205	kN	
Bearing reaction force	[Fr]	20.787	kN	(-112.5°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.061	mrاد	(-0.21')
Misalignment of bearing	[ry]	1.967	mrاد	(6.76')
Misalignment of bearing	[rz]	0.025	mrاد	(0.09')
Misalignment of bearing	[rr]	0.066	mrاد	(0.23')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	0.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-4541.00	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	-0.008	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.020	mm	
Displacement of bearing	[ur]	0.022	mm	(-111.35°)
Misalignment of bearing	[rx]	0.065	mrاد	(0.22')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	-0.025	mrاد	(-0.09')
Misalignment of bearing	[rr]	0.069	mrاد	(0.24')

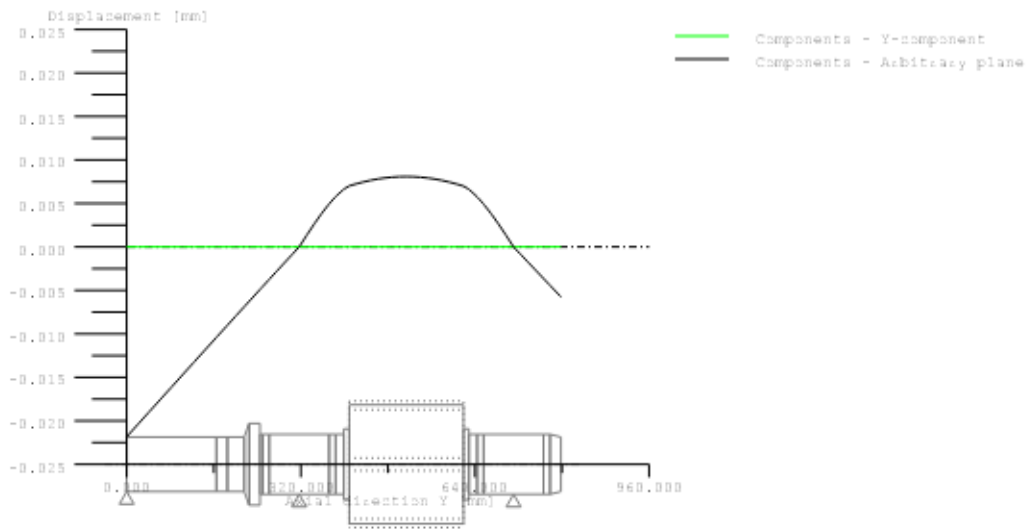
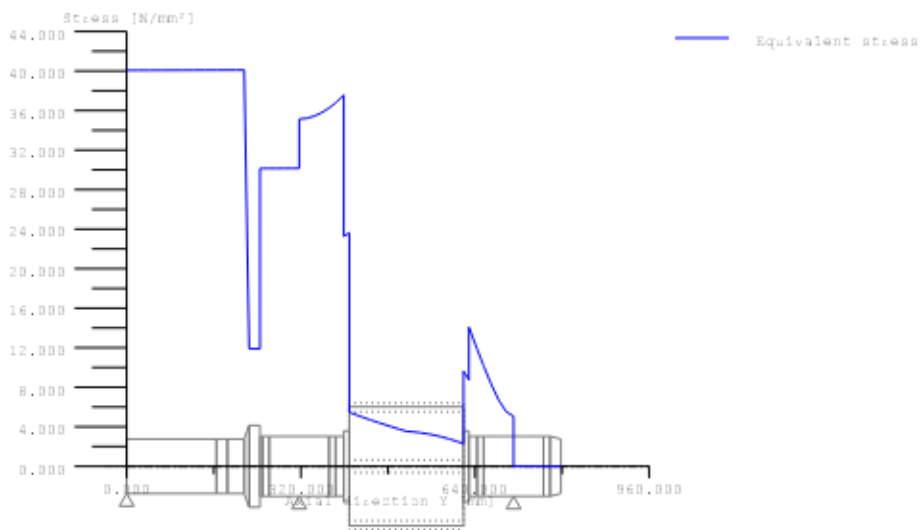


Figure: Displacement (bending etc.) (Arbitrary plane 68.64945743 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	245.10	Smooth shaft
2	317.00	Smooth shaft
3	399.00	Own Input
4	629.00	Own Input
5	655.00	Smooth shaft
6	766.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.82	10.87	8.09
2	1.00	0.92	0.82	10.86	8.09
3	1.00	0.92	0.82	8.16	7.41
4	1.00	0.92	0.82	14.42	18.57
5	1.00	0.92	0.82	21.11	27.18
6	1.00	0.92	0.82	10000.00	10000.00

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

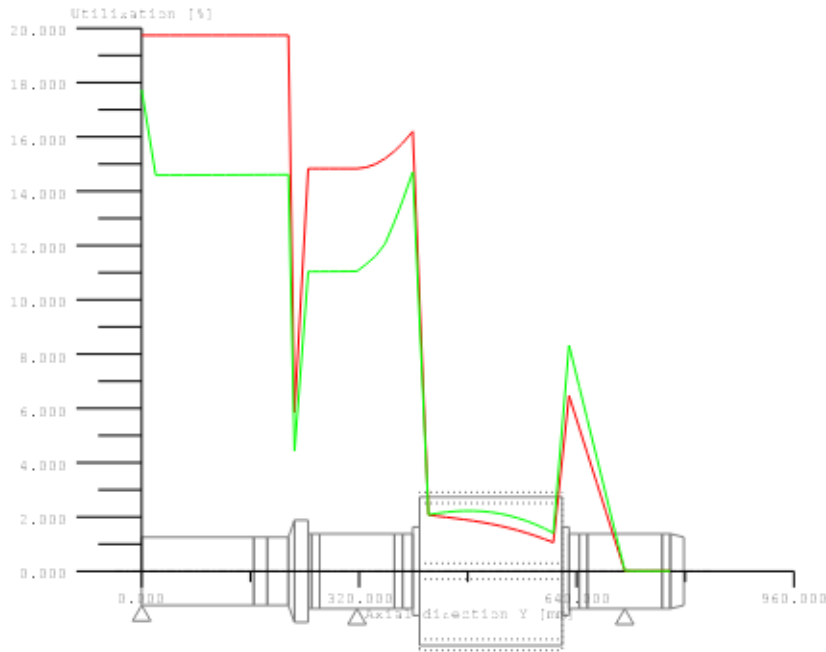


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 798.00
 Speed (1/min) [n] 1073.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 220.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 492.83
 [sigSeff] (N/mm²) 344.98
 [sigbF] (N/mm²) 413.98
 [tautF] (N/mm²) 239.01
 [sigzdW] (N/mm²) 197.13
 [sigbW] (N/mm²) 246.41
 [tautW] (N/mm²) 147.85

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	245.10
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (μm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	18.3	2270.5	166.3
Maximum value	-0.0	31.2	7719.7	282.7
Cross section, moment of resistance: (mm^2)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm^2)				
[sigzdm, sigbm, taum, tauqm] (N/mm^2)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm^2)	0.000	0.140	8.688	0.023
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm^2)	-0.000	0.239	29.539	0.040

Technological size influence	[K1 (sigB)]	0.704
	[K1 (sigS)]	0.704

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821
Influence coefficient surface roughness	[KF]	0.922	0.955
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.084	1.265

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm^2)	[sigmV]	15.048		
Equivalent mean stress (N/mm^2)	[taumV]	8.688		
Fatigue limit of part (N/mm^2)	[sigWK]	181.792	189.136	116.848
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.226	0.237	0.134
Permissible amplitude (N/mm^2)	[sigADK]	0.023	3.827	102.996
Margin of safety endurance limit	[S]		10.871	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		905.9	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm^2)	[sigFK]	344.980	413.976	239.009
Margin of safety yield stress	[S]		8.091	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		674.3	

Cross section '2' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	317.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (μm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	32.2	2270.5	213.8
Maximum value	-0.0	54.7	7719.7	363.4
Cross section, moment of resistance: (mm^2)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm^2)				
[sigzdm, sigbm, taum, tauqm] (N/mm^2)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm^2)	0.000	0.246	8.688	0.030
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm^2)	-0.000	0.419	29.539	0.051

Technological size influence	[K1 (sigB)]	0.704
	[K1 (sigS)]	0.704

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.922	0.922	0.955
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.084	1.303	1.265

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	181.792	189.136	116.848
Influence coeff. mean stress sensitivity.	[PsigK]	0.226	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.023	6.666	102.996
Margin of safety endurance limit	[S]		10.859	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		904.9	

Present margin of safety for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	344.980	413.976	239.009
Margin of safety yield stress	[S]		8.091	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		674.3	

Cross section '3' Own Input

Comment		
Position (Y-Coordinate) (mm)	[y]	399.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Own Input		
Mean roughness (µm)	[Rz]	8.000

		Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	1729.9	2270.5	20756.1
Maximum value		-0.0	2940.9	7719.7	35285.4
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		9503.3	130671	261341	9503.3

Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	13.239	8.688	2.912
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	22.506	29.539	4.951

Technological size influence	[K1 (sigB)]	0.704
	[K1 (sigS)]	0.704

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.922	0.922	0.955
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.084	1.303	1.265

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	181.792	189.136	116.848
Influence coeff. mean stress sensitivity.	[PsigK]	0.226	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	0.023	148.937	102.996
Margin of safety endurance limit	[S]		8.161	

Required safety	[Smin]	1.200		
Result (%)	[S/Smin]	680.0		
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	344.980	413.976	239.009
Margin of safety yield stress	[S]		7.406	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		617.2	

Cross section '4' Own Input

Comment				
Position (Y-Coordinate) (mm)	[y]		629.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Own Input				
Mean roughness (µm)	[Rz]		8.000	
Tension/Compression Bending Torsion Shearing				
Stress: (N) (Nm)				
Mean value		-0.0	0.0	0.0 0.0
Amplitude		0.0	1714.0	0.0 20904.5
Maximum value		-0.0	2913.7	0.0 35537.6
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]		9503.3	130671	261341 9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	0.000 0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	13.117	0.000 2.933
[sigzdm, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	22.298	0.000 4.986

Technological size influence	[K1(sigB)]		0.704	
	[K1(sigS)]		0.704	

Tension/Compression Bending Torsion				
Notch effect coefficient	[beta(dB)]	0.000	0.000	0.000
[dB] (mm) = 0.0				
Geometrical size influence	[K3(d)]	0.000	0.000	0.000
Geometrical size influence	[K3(dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.922	0.922	0.955
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.084	1.303	1.265

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	181.792	189.136	116.848
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.226	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	181.792	189.136	116.848
Margin of safety endurance limit	[S]		14.419	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1201.6	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	344.980	413.976	239.009
Margin of safety yield stress	[S]		18.565	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1547.1	

Cross section '5' Smooth shaft

Comment				
Position (Y-Coordinate) (mm)	[y]		655.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Smooth shaft				
Mean roughness (µm)	[Rz]		8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	1170.8	0.0	20885.9
Maximum value	-0.0	1990.4	0.0	35506.1
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	8.960	0.000	2.930
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	15.232	0.000	4.982

Technological size influence	[K1 (sigB)]	0.704
	[K1 (sigS)]	0.704

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821
Influence coefficient surface roughness	[KF]	0.922	0.922
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.084	1.303

Present margin of safety for endurance limit:			
Equivalent mean stress (N/mm ²)	[sigmV]	0.000	
Equivalent mean stress (N/mm ²)	[taumV]	0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	181.792	189.136
Influence coeff. mean stress sensitivity.			
	[PsigK]	0.226	0.237
Permissible amplitude (N/mm ²)	[sigADK]	181.792	189.136
Margin of safety endurance limit	[S]	21.109	
Required safety	[Smin]	1.200	
Result (%)	[S/Smin]	1759.1	

Present margin of safety for proof against exceed of yield point:			
Static notch sensitivity factor	[K2F]	1.000	1.200
Increase coefficient	[gammaF]	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	344.980	413.976
Margin of safety yield stress	[S]	27.178	
Required safety	[Smin]	1.200	
Result (%)	[S/Smin]	2264.9	

Cross section '6' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	766.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	0.3	0.0	27.1
Maximum value	-0.0	0.6	0.0	46.1
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.003	0.000	0.004
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.004	0.000	0.006

Technological size influence	[K1 (sigB)]	0.704
	[K1 (sigS)]	0.704

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000

Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.922	0.922	0.955
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.084	1.303	1.265

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	181.792	189.136	116.848
Influence coeff. mean stress sensitivity.	[PsigK]	0.226	0.237	0.134
Permissible amplitude (N/mm ²)	[sigADK]	181.792	189.136	116.848
Margin of safety endurance limit	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety

for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	344.980	413.976	239.009
Margin of safety yield stress	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
The reference diameter for the notch number is not defined.
Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
The notching factor for the light fit case is no longer defined in DIN 743.
The values are imported from the FKM-Guideline..

End report

lines: 710

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z7
Changed by : jirisuch on: 14.03.2014 at: 17:47:29

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	1073.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	165.288
Mass moment of inertia (kg*m ²)	0.898
Momentum of mass GD2 (Nm ²)	35.218
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

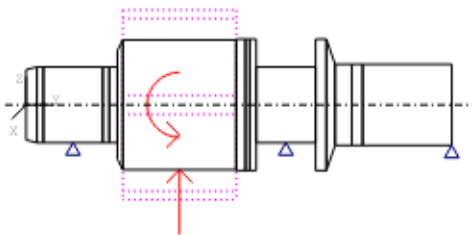
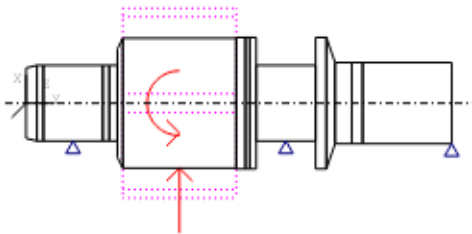


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone)	y= 0.00...20.00 (mm)
dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 20.00...32.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 32.00...142.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 1.8	
Cylinder (Cylinder)	y= 142.00...154.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 154.00...169.00 (mm)
d=140.00 (mm), l=15.00 (mm), Rz= 8.0	
Taper (Cone)	y= 169.00...179.00 (mm)
dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	
Cylinder (z7 nahrada)	y= 179.00...389.00 (mm)
d=240.00 (mm), l=210.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 389.00...406.00 (mm)
d=243.00 (mm), l=17.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 406.00...414.00 (mm)
d=243.00 (mm), l=8.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 414.00...426.00 (mm)
d=243.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 426.00...536.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 2.8	
Relief groove left (Relief groove left)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder)	y= 536.00...556.00 (mm)
d=243.00 (mm), l=20.00 (mm), Rz=32.0	
Taper (Cone)	y= 556.00...572.00 (mm)
dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 572.00...603.00 (mm)
d=150.00 (mm), l=31.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 603.00...623.00 (mm)
d=150.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 623.00...788.00 (mm)
d=150.00 (mm), l=165.00 (mm), Rz=16.0	

Inner contour

Forces

Cylindrical gear (z7 i78)	y= 284.00 (mm)		
Operating pitch diameter	(mm)	350.7216	
Helix angle	(°)	24.5828	Double helical gearing, right-left
Working pressure angle at normal section(°)		17.3265	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driving (Output)
Torque	(Nm)	4541.0000	
Axial force	(N)	0.0000	
Shearing force X	(N)	8883.7986	
Shearing force Z	(N)	25895.1793	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 4.67 μm (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 371.1 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.03 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	-4.442	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-12.504	kN	
Bearing reaction force	[Fr]	13.270	kN	(-109.56°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.015	mrاد	(0.05')
Misalignment of bearing	[ry]	0.450	mrاد	(1.55')
Misalignment of bearing	[rz]	-0.005	mrاد	(-0.02')
Misalignment of bearing	[rr]	0.016	mrاد	(0.05')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	-4.442	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	-11.768	kN	
Bearing reaction force	[Fr]	12.579	kN	(-110.68°)
Displacement of bearing	[ux]	0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.013	mrاد	(-0.05')
Misalignment of bearing	[ry]	0.342	mrاد	(1.18')
Misalignment of bearing	[rz]	0.004	mrاد	(0.02')
Misalignment of bearing	[rr]	0.014	mrاد	(0.05')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-4541.00	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	-0.001	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.004	mm	
Displacement of bearing	[ur]	0.005	mm	(-106.71°)
Misalignment of bearing	[rx]	-0.015	mrاد	(-0.05')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.004	mrاد	(0.02')

Misalignment of bearing [rr] 0.015 mrad (0.05')

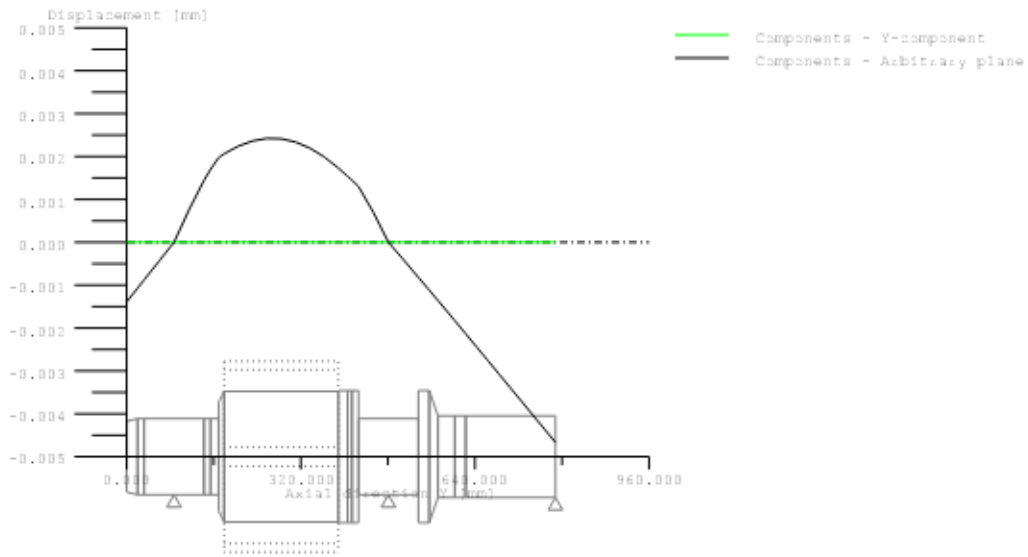
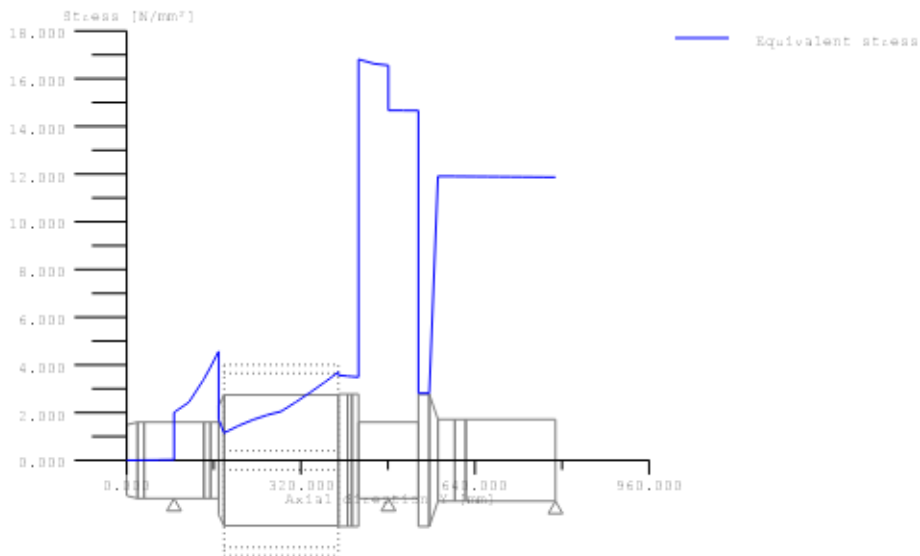


Figure: Displacement (bending etc.) (Arbitrary plane 73.29485914 °)



$$\text{GEH(von Mises): } \sigma_V = ((\sigma_B + \sigma_Z, D)^2 + 3 * (\tau_T + \tau_S)^2)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.80	44.46	58.22
3	3.32	0.87	0.80	10.76	16.06
2	3.32	0.87	0.80	9.12	15.83

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

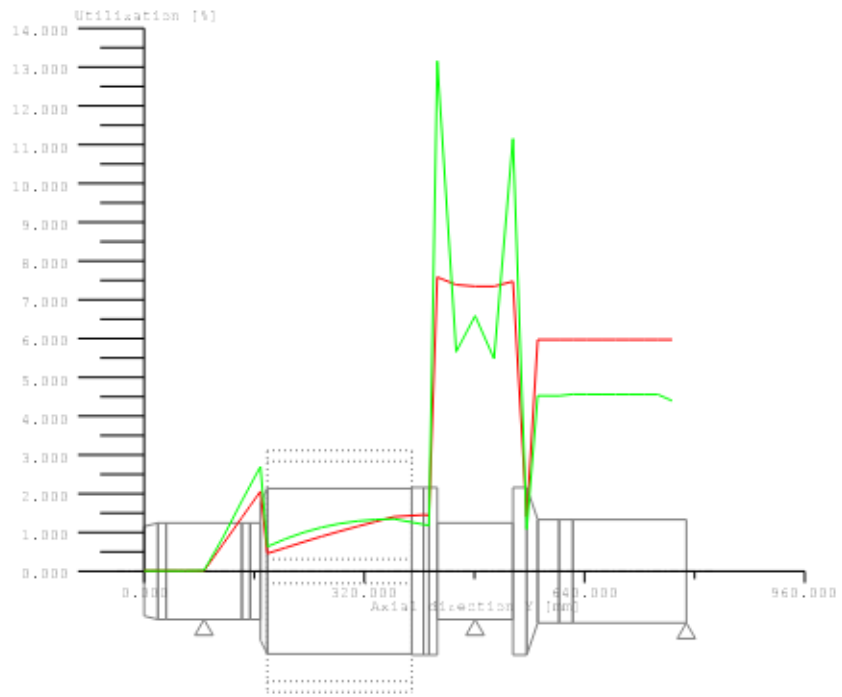


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 1073.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 250.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 482.72
 [sigSeff] (N/mm²) 337.91
 [sigbF] (N/mm²) 405.49
 [tautF] (N/mm²) 234.11
 [sigzdW] (N/mm²) 193.09
 [sigbW] (N/mm²) 241.36
 [tautW] (N/mm²) 144.82

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	1103.6	0.0	13448.2
Maximum value	0.0	1876.2	0.0	22862.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	4.097	0.000	1.165
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	0.000	6.964	0.000	1.980

Technological size influence	[K1 (sigB)]	0.690
	[K1 (sigS)]	0.690

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) =	0.0		
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.924	0.956
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.082	1.289

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	0.000		
Equivalent mean stress (N/mm ²)	[taumV]	0.000		
Fatigue limit of part (N/mm ²)	[sigWK]	178.410	182.143	112.387
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.227	0.233	0.132
Permissible amplitude (N/mm ²)	[sigADK]	178.410	182.143	112.387
Margin of safety endurance limit	[S]		44.460	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		3705.0	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	337.907	405.489	234.109
Margin of safety yield stress	[S]		58.222	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		4851.9	

Cross section '3' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]	536.00			
External diameter (mm)	[da]	140.000			
Inner diameter (mm)	[di]	0.000			
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]				32.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	43.9	2270.5	420.0
Maximum value	-0.0	74.6	7719.7	714.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.166	4.287	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.282	14.576	0.063

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.052	10.185	46.858
Margin of safety endurance limit	[S]		10.761	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		896.7	
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		16.060	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1338.3	

Cross section '2' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]		426.00		
External diameter (mm)	[da]		140.000		
Inner diameter (mm)	[di]		0.000		
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]		32.000		
				Tension/Compression	Bending Torsion Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	781.9	2270.5	13099.5
Maximum value		-0.0	1329.2	7719.7	22269.1
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4
Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	4.287	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	2.953	4.287	1.148
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	5.020	14.576	1.951

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932
Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	7.426		
Equivalent mean stress (N/mm ²)	[taumV]	4.287		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.052	48.910	46.858
Margin of safety endurance limit	[S]		9.123	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		760.2	

Present margin of safety
 for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		15.826	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1318.8	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
 The reference diameter for the notch number is not defined.
 Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
 The notching factor for the light fit case is no longer defined in DIN 743.
 The values are imported from the FKM-Guideline..

End report

lines: 531

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z77
Changed by : jirisuch on: 14.03.2014 at: 17:48:55

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	788.000
Speed (1/min)	855.00
Sense of rotation: counter clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	165.288
Mass moment of inertia (kg*m ²)	0.898
Momentum of mass GD2 (Nm ²)	35.218
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

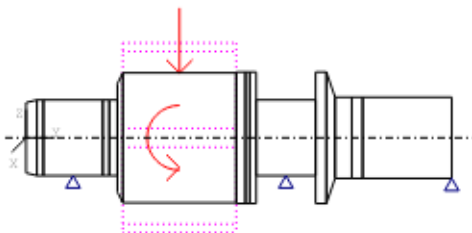
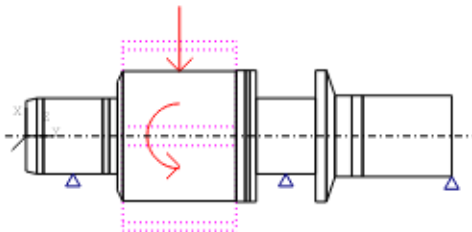


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Taper (Cone)	y= 0.00...20.00 (mm)
dl=130.00 (mm), dr=140.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 20.00...32.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 32.00...142.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 1.8	
Cylinder (Cylinder)	y= 142.00...154.00 (mm)
d=140.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 154.00...169.00 (mm)
d=140.00 (mm), l=15.00 (mm), Rz= 8.0	
Taper (Cone)	y= 169.00...179.00 (mm)
dl=200.00 (mm), dr=240.00 (mm), l=10.00 (mm), Rz= 8.0	
Cylinder (z7 nahrada)	y= 179.00...389.00 (mm)
d=240.00 (mm), l=210.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 389.00...406.00 (mm)
d=243.00 (mm), l=17.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 406.00...414.00 (mm)
d=243.00 (mm), l=8.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 414.00...426.00 (mm)
d=243.00 (mm), l=12.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 426.00...536.00 (mm)
d=140.00 (mm), l=110.00 (mm), Rz= 2.8	
Relief groove left (Relief groove left)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Relief groove right (Relief groove right)	
r=1.20 (mm), t=0.40 (mm), l=4.00 (mm), Rz=32.0	
Form F (DIN 509), Series 1, with the usual stressing	
Cylinder (Cylinder)	y= 536.00...556.00 (mm)
d=243.00 (mm), l=20.00 (mm), Rz=32.0	
Taper (Cone)	y= 556.00...572.00 (mm)
dl=243.00 (mm), dr=150.00 (mm), l=16.00 (mm), Rz=32.0	
Cylinder (Cylinder)	y= 572.00...603.00 (mm)
d=150.00 (mm), l=31.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 603.00...623.00 (mm)
d=150.00 (mm), l=20.00 (mm), Rz= 8.0	
Cylinder (Cylinder)	y= 623.00...788.00 (mm)
d=150.00 (mm), l=165.00 (mm), Rz=16.0	

Inner contour

Forces

Cylindrical gear (z7 i87)	y= 284.00 (mm)		
Operating pitch diameter	(mm)	350.7216	
Helix angle	(°)	24.5828	Double helical gearing, right-left
Working pressure angle at normal section(°)		17.3265	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driving (Output)
Torque	(Nm)	5698.8222	
Axial force	(N)	0.0000	
Shearing force X	(N)	-11148.9074	
Shearing force Z	(N)	-32497.6929	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 87.00 (mm)

Degrees of freedom
X: fixed, Y: free, Z: fixed
Rx: free, Ry: free, Rz: free

Fixed bearing adjusted on both sides (prave radialni+axialni) y= 481.00 (mm)

Degrees of freedom
X: fixed, Y: fixed, Z: fixed
Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 788.00 (mm)

Degrees of freedom
X: free, Y: free, Z: free
Rx: free, Ry: fixed, Rz: free

maximum deflection 4.66 μm (Shaft 1, 788.00 (mm))

Center of mass

Shaft 1 371.1 mm

Deformation due to torsion

Shaft 1 [phi.t] -0.03 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	87.00	mm	
Bearing reaction force	[Fx]	5.574	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	16.692	kN	
Bearing reaction force	[Fr]	17.598	kN	(71.53°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.019	mrاد	(-0.07')
Misalignment of bearing	[ry]	0.565	mrاد	(1.94')
Misalignment of bearing	[rz]	0.007	mrاد	(0.02')
Misalignment of bearing	[rr]	0.020	mrاد	(0.07')

Shaft 'Shaft 1' Bearing 'prave radialni+axialni'

Position (Y-coordinate)	[y]	481.00	mm	
Bearing reaction force	[Fx]	5.574	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	17.428	kN	
Bearing reaction force	[Fr]	18.298	kN	(72.26°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.015	mrاد	(0.05')
Misalignment of bearing	[ry]	0.429	mrاد	(1.48')
Misalignment of bearing	[rz]	-0.005	mrاد	(-0.02')
Misalignment of bearing	[rr]	0.016	mrاد	(0.06')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	788.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-5698.82	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.002	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.004	mm	
Displacement of bearing	[ur]	0.005	mm	(68.83°)
Misalignment of bearing	[rx]	0.014	mrاد	(0.05')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	-0.005	mrاد	(-0.02')

Misalignment of bearing [rr] 0.015 mrad (0.05')

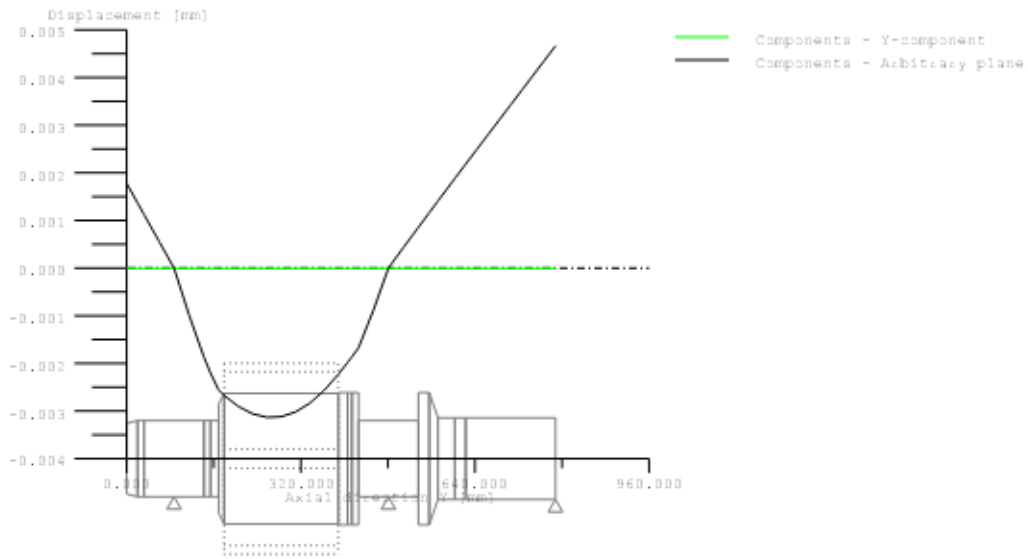
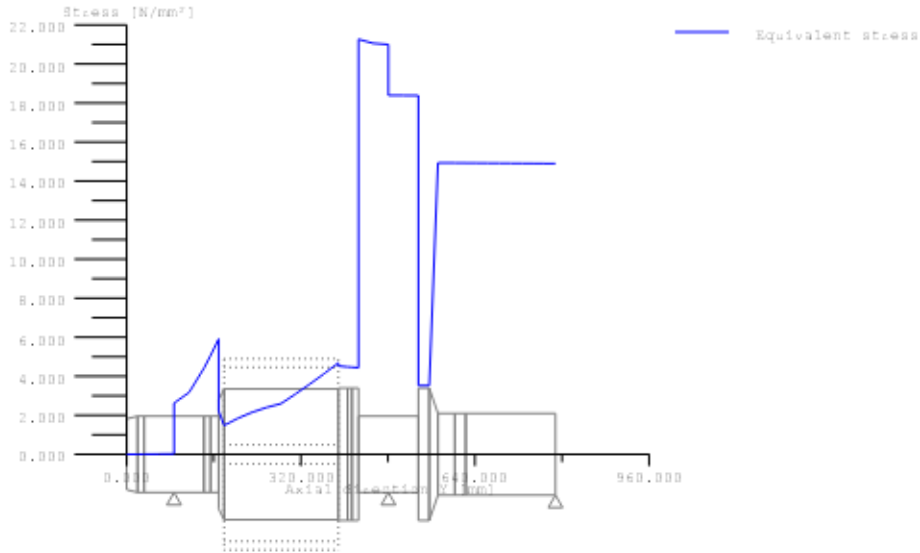


Figure: Displacement (bending etc.) (Arbitrary plane 68.8319976 °)



$$\text{GEH(von Mises): } \sigma_V = ((\sigma_B + \sigma_Z, D)^2 + 3 * (\tau_T + \tau_S)^2)^{1/2}$$

Figure: Equivalent stress

**Strength calculation as specified in
 DIN 743:2000**

Summary

Label Shaft 1
 Drawing

Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

Calculation of endurance limit and the static strength
 Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	168.99	Smooth shaft
3	536.00	Shoulder with relief groove
2	426.00	Shoulder with relief groove

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.92	0.80	34.38	45.02
3	3.32	0.87	0.80	8.58	12.80
2	3.32	0.87	0.80	7.40	12.63

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
 Kfsig: Surface factor
 K2d: Size coefficient bending
 SD: Safety endurance limit
 SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

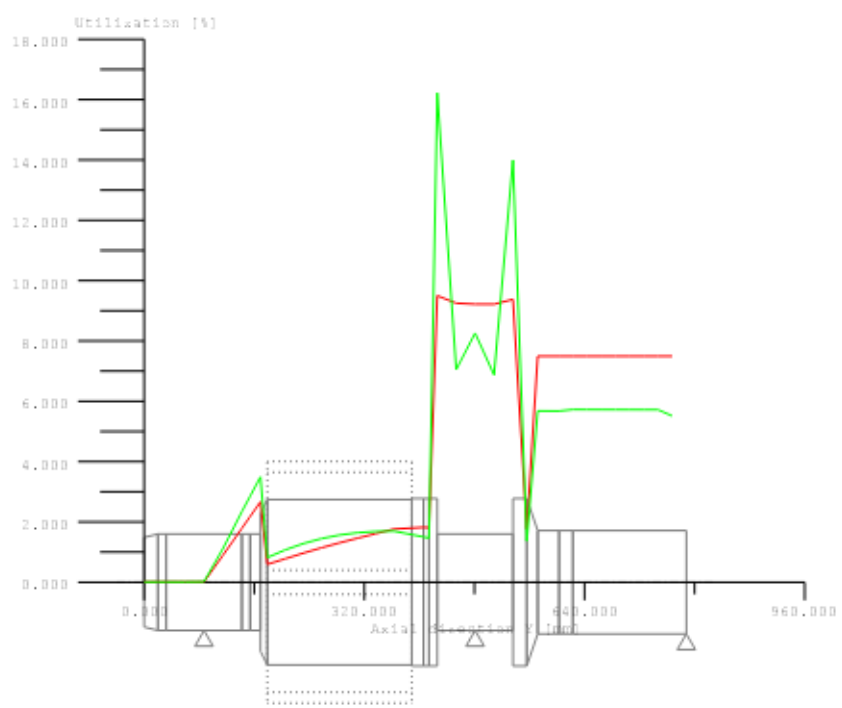


Figure: Strength

Calculation details:

General statements

Label Shaft 1
 Drawing
 Length (mm) [l] 788.00
 Speed (1/min) [n] 855.00
 Material C45 (1)
 Material type Through hardened steel
 Material treatment unalloyed, through hardened
 Surface treatment No

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm) [dB] 16.00
 sigB according DIN 743 (at dB) (N/mm²) [sigB] 700.00
 sigS according DIN 743 (at dB) (N/mm²) [sigS] 490.00
 [sigzdW] (bei dB) (N/mm²) 280.00
 [sigbW] (bei dB) (N/mm²) 350.00
 [tautW] (bei dB) (N/mm²) 210.00
 Thickness of raw material (mm) [dWerkst] 250.00
 Material data calculated according DIN743/3 with Kl(d)
 Material strength calculated from size of raw material
 Geometric size coefficient Kl(d) calculated from raw material diameter
 [sigBeff] (N/mm²) 482.72
 [sigSeff] (N/mm²) 337.91
 [sigbF] (N/mm²) 405.49
 [tautF] (N/mm²) 234.11
 [sigzdW] (N/mm²) 193.09
 [sigbW] (N/mm²) 241.36
 [tautW] (N/mm²) 144.82

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft
 Comment

Position (Y-Coordinate) (mm)	[y]	168.99
External diameter (mm)	[da]	140.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	0.0	0.0	0.0	0.0
Amplitude	0.0	1427.2	0.0	17419.0
Maximum value	0.0	2426.2	0.0	29612.3
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15393.8	269392	538783	15393.8

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	5.298	0.000	1.509
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	0.000	9.006	0.000	2.565

Technological size influence	[K1 (sigB)]	0.690
	[K1 (sigS)]	0.690

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) =	0.0		
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.805
Influence coefficient surface roughness	[KF]	0.924	0.924
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.082	1.325

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	0.000		
Equivalent mean stress (N/mm ²)	[taumV]	0.000		
Fatigue limit of part (N/mm ²)	[sigWK]	178.410	182.143	112.387
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.227	0.233	0.132
Permissible amplitude (N/mm ²)	[sigADK]	178.410	182.143	112.387
Margin of safety endurance limit	[S]		34.381	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		2865.1	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	337.907	405.489	234.109
Margin of safety yield stress	[S]		45.023	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		3752.0	

Cross section '3' Shoulder with relief groove

Comment					
Position (Y-Coordinate) (mm)	[y]	536.00			
External diameter (mm)	[da]	140.000			
Inner diameter (mm)	[di]	0.000			
Notch effect Shoulder with relief groove					
[D, d, D1, r, t] (mm)		243.00	139.20	140.00	1.20 0.40
Shape B					
Mean roughness (µm)	[Rz]				32.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2849.4	0.0
Amplitude	0.0	43.9	2849.4	420.0
Maximum value	-0.0	74.6	9688.0	714.0
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	15218.4	264800	529600	15218.4

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	5.380	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.166	5.380	0.037
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.282	18.293	0.063

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	9.319		
Equivalent mean stress (N/mm ²)	[taumV]	5.380		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054
Permissible amplitude (N/mm ²)	[sigADK]	0.042	8.152	46.858
Margin of safety endurance limit	[S]		8.576	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		714.6	

Present margin of safety for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		12.797	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1066.4	

Cross section '2' Shoulder with relief groove

Comment

Position (Y-Coordinate) (mm)	[y]	426.00		
External diameter (mm)	[da]	140.000		
Inner diameter (mm)	[di]	0.000		
Notch effect Shoulder with relief groove				
[D, d, D1, r, t] (mm)		243.00	139.20	140.00 1.20 0.40
Shape B				
Mean roughness (µm)	[Rz]		32.000	

			Tension/Compression	Bending Torsion	Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2849.4	0.0
Amplitude		0.0	915.9	2849.4	17770.0
Maximum value		-0.0	1557.0	9688.0	30209.1
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		15218.4	264800	529600	15218.4

Stresses: (N/mm²)

[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	5.380	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	3.459	5.380	1.557
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	5.880	18.293	2.647

Technological size influence	[K1 (sigB)]	0.690		
	[K1 (sigS)]	0.690		
			Tension/Compression	Bending Torsion
Stress concentration factor	[alfa]	4.803	4.037	2.649
References stress slope	[G']	1.917	1.917	0.958
Notch sensitivity factor n	[n]	1.217	1.217	1.154
Notch effect coefficient	[beta]	3.946	3.316	2.296
Geometrical size influence	[K2 (d)]	1.000	0.805	0.805
Influence coefficient surface roughness	[KF]	0.873	0.873	0.927
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	4.091	4.267	2.932

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	9.319		
Equivalent mean stress (N/mm ²)	[taumV]	5.380		
Fatigue limit of part (N/mm ²)	[sigWK]	47.195	56.565	49.384
Influence coeff. mean stress sensitivity.	[PsisigK]	0.051	0.062	0.054

Permissible amplitude (N/mm ²)	[sigADK]	0.042	48.442	46.858
Margin of safety endurance limit	[S]		7.396	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		616.3	

Present margin of safety
 for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.150	1.150	1.000
Yield stress of part (N/mm ²)	[sigFK]	388.593	466.312	234.109
Margin of safety yield stress	[S]		12.634	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1052.9	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
 The reference diameter for the notch number is not defined.
 Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
 The notching factor for the light fit case is no longer defined in DIN 743.
 The values are imported from the FKM-Guideline..

End report

lines: 531

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_____ Project _____
Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z8
Changed by : jirisuch on: 14.03.2014 at: 17:49:35

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	1348.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	133.783
Mass moment of inertia (kg*m ²)	0.866
Momentum of mass GD2 (Nm ²)	33.989
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

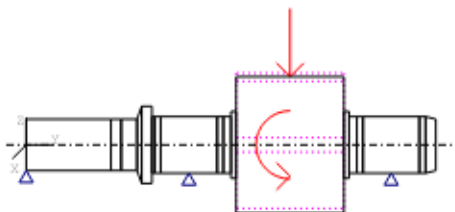
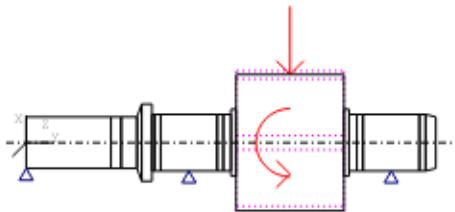


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z8 nahrada) d=265.27 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z8 i78)			y= 514.00 (mm)
Operating pitch diameter	(mm)	279.2784	
Helix angle	(°)	24.5828	Double helical gearing, left-right
Working pressure angle at normal section(°)		17.3265	
Position of contact point	(°)	0.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	3614.6091	
Axial force	(N)	0.0000	
Shearing force X	(N)	-8880.4268	
Shearing force Z	(N)	-25885.3509	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vystup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 11.68 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 465.0 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.09 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm	
Bearing reaction force	[Fx]	4.440	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	13.752	kN	
Bearing reaction force	[Fr]	14.451	kN	(72.11°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	-0.036	mrاد	(-0.13')
Misalignment of bearing	[ry]	1.267	mrاد	(4.36')
Misalignment of bearing	[rz]	0.013	mrاد	(0.04')
Misalignment of bearing	[rr]	0.039	mrاد	(0.13')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm	
Bearing reaction force	[Fx]	4.440	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	13.446	kN	
Bearing reaction force	[Fr]	14.160	kN	(71.73°)
Displacement of bearing	[ux]	-0.000	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	-0.000	mm	
Displacement of bearing	[ur]	0.000	mm	
Misalignment of bearing	[rx]	0.038	mrاد	(0.13')
Misalignment of bearing	[ry]	1.554	mrاد	(5.34')
Misalignment of bearing	[rz]	-0.013	mrاد	(-0.04')
Misalignment of bearing	[rr]	0.040	mrاد	(0.14')

Shaft 'Shaft 1' Bearing 'vystup'

Position (Y-coordinate)	[y]	0.00	mm	
Bearing reaction force	[Fx]	0.000	kN	
Bearing reaction force	[Fy]	0.000	kN	
Bearing reaction force	[Fz]	0.000	kN	
Bearing reaction force	[Fr]	0.000	kN	
Bearing reaction moment	[Mx]	0.00	Nm	
Bearing reaction moment	[My]	-3614.61	Nm	
Bearing reaction moment	[Mz]	0.00	Nm	
Bearing reaction moment	[Mr]	0.00	Nm	(0°)
Displacement of bearing	[ux]	0.004	mm	
Displacement of bearing	[uy]	0.000	mm	
Displacement of bearing	[uz]	0.011	mm	
Displacement of bearing	[ur]	0.012	mm	(70°)
Misalignment of bearing	[rx]	-0.034	mrاد	(-0.12')
Misalignment of bearing	[ry]	0.000	mrاد	(0')
Misalignment of bearing	[rz]	0.013	mrاد	(0.04')
Misalignment of bearing	[rr]	0.036	mrاد	(0.13')

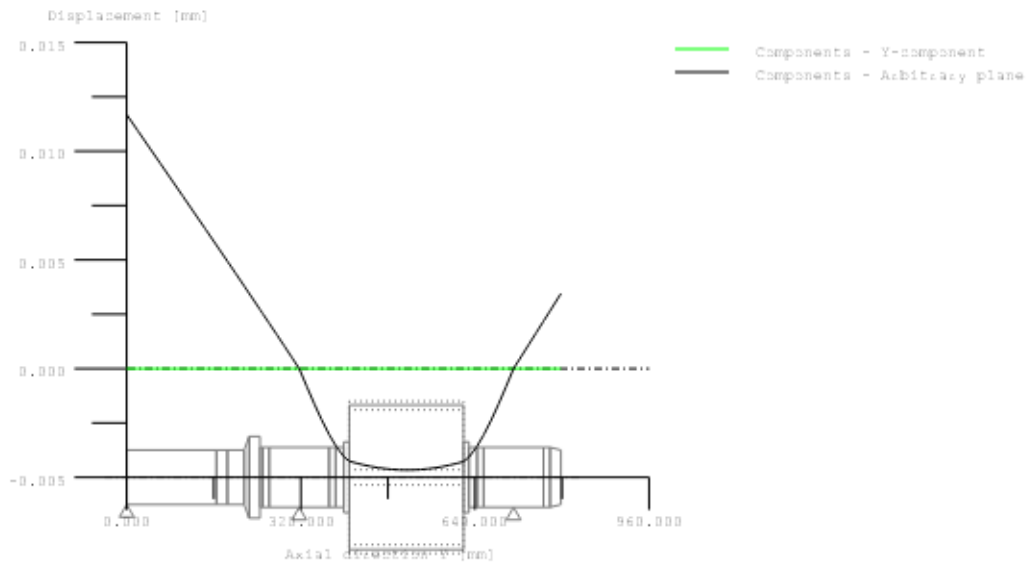
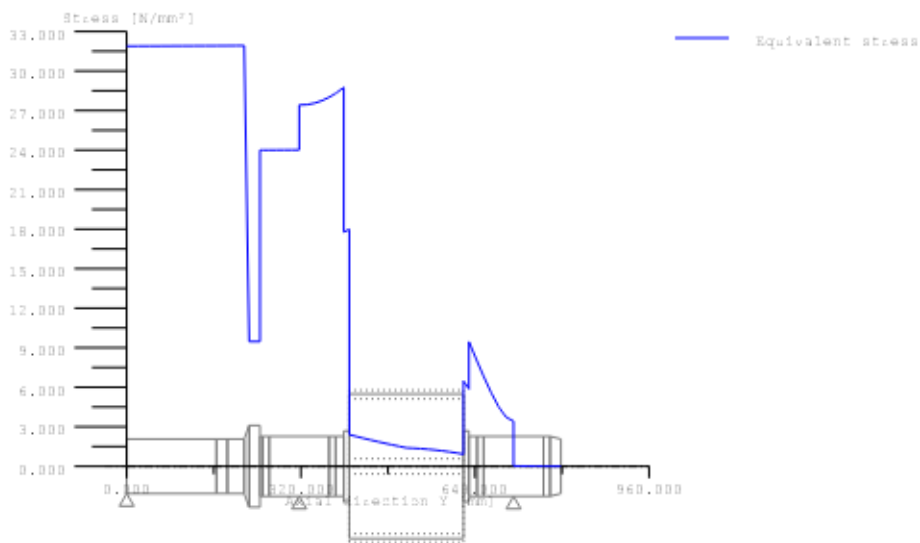
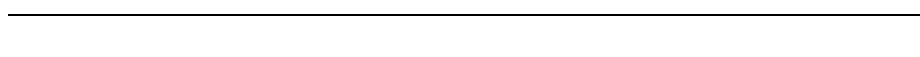


Figure: Displacement (bending etc.) (Arbitrary plane 70.00153955 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress



End report

lines: 220

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Name : prevodovka_zkusebna

_____ File _____
Name : hridel_z88
Changed by : jirisuch on: 14.03.2014 at: 17:50:34

Analysis of shafts, axle and beams

Input data

Coordinate system shaft: see picture W-002

Label	Shaft 1
Drawing	
Initial position (mm)	0.000
Length (mm)	798.000
Speed (1/min)	1073.00
Sense of rotation: clockwise	
Material	C45 (1)
Young's modulus (N/mm ²)	206000.000
Poisson's ratio nu	0.300
Specific weight (kg/m ³)	7830.000
Warmth elongation coefficient (10 ⁻⁶ /K)	11.500
Temperature (°C)	20.000
Weight of shaft (kg)	133.783
Mass moment of inertia (kg*m ²)	0.866
Momentum of mass GD2 (Nm ²)	33.989
Position in space (°)	0.000
Consider deformations due to shearing	
Shear correction coefficient	1.100
Contact angle of roller bearings is considered	
Reference temperature (°C)	20.000

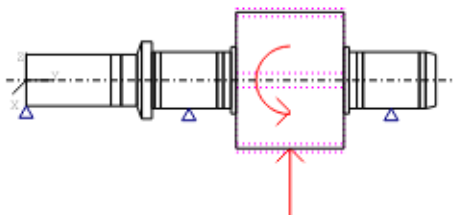
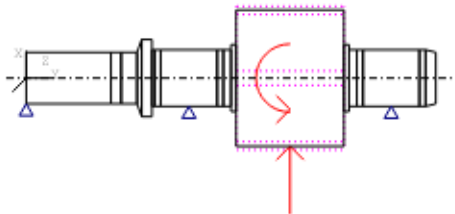


Figure: Load applications

SHAFT DEFINITION (Shaft 1)

Outer contour

Cylinder (Cylinder) d=100.00 (mm), l=165.00 (mm), Rz= 8.0	y= 0.00...165.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 165.00...185.00 (mm)
Cylinder (Cylinder) d=100.00 (mm), l=31.00 (mm), Rz= 8.0	y= 185.00...216.00 (mm)
Taper (Cone) dl=100.00 (mm), dr=150.00 (mm), l=9.00 (mm), Rz= 8.0	y= 216.00...225.00 (mm)
Cylinder (Cylinder) d=150.00 (mm), l=20.00 (mm), Rz= 8.0	y= 225.00...245.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=5.00 (mm), Rz= 8.0	y= 245.00...250.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 250.00...262.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 262.00...372.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 372.00...384.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 384.00...399.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 399.00...409.00 (mm)
Cylinder (z8 nahrada) d=265.27 (mm), l=210.00 (mm), Rz= 8.0	y= 409.00...619.00 (mm)
Cylinder (Cylinder) d=130.00 (mm), l=10.00 (mm), Rz= 8.0	y= 619.00...629.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=15.00 (mm), Rz= 8.0	y= 629.00...644.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 644.00...656.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=110.00 (mm), Rz= 8.0	y= 656.00...766.00 (mm)
Cylinder (Cylinder) d=110.00 (mm), l=12.00 (mm), Rz= 8.0	y= 766.00...778.00 (mm)
Taper (Cone) dl=110.00 (mm), dr=100.00 (mm), l=20.00 (mm), Rz= 8.0	y= 778.00...798.00 (mm)

Inner contour

Forces

Cylindrical gear (z8 i87)			y= 514.00 (mm)
Operating pitch diameter	(mm)	279.2784	
Helix angle	(°)	24.5828	Double helical gearing, left-right
Working pressure angle at normal section(°)		17.3265	
Position of contact point	(°)	180.0000	
Length of load application	(mm)	210.0000	
Power	(kW)	510.2463	driven (Input)
Torque	(Nm)	4541.0000	
Axial force	(N)	0.0000	
Shearing force X	(N)	11156.3982	
Shearing force Z	(N)	32519.5275	
Bending moment X	(Nm)	0.0000	
Bending moment Z	(Nm)	0.0000	

Bearing

Free bearing (leve radialni) y= 317.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Free bearing (prave radialni) y= 711.00 (mm)
 Degrees of freedom
 X: fixed, Y: free, Z: fixed
 Rx: free, Ry: free, Rz: free

Own Input (vstup) y= 0.00 (mm)
 Degrees of freedom
 X: free, Y: free, Z: free
 Rx: free, Ry: fixed, Rz: free

maximum deflection 16.10 μm (Shaft 1, 0.00 (mm))

Center of mass
 Shaft 1 465.0 mm

Deformation due to torsion
 Shaft 1 [phi.t] 0.11 °

Roller bearings, classical calculation (contact angle considered)

Shaft 'Shaft 1' Bearing 'leve radialni'

Position (Y-coordinate)	[y]	317.00	mm
Bearing reaction force	[Fx]	-5.578	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-15.450	kN
Bearing reaction force	[Fr]	16.426	kN (-109.85°)
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	0.046	mrاد (0.16')
Misalignment of bearing	[ry]	1.592	mrاد (5.47')
Misalignment of bearing	[rz]	-0.016	mrاد (-0.05')
Misalignment of bearing	[rr]	0.049	mrاد (0.17')

Shaft 'Shaft 1' Bearing 'prave radialni'

Position (Y-coordinate)	[y]	711.00	mm
Bearing reaction force	[Fx]	-5.578	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	-15.757	kN
Bearing reaction force	[Fr]	16.715	kN (-109.49°)
Displacement of bearing	[ux]	0.000	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	0.000	mm
Displacement of bearing	[ur]	0.000	mm
Misalignment of bearing	[rx]	-0.045	mrاد (-0.16')
Misalignment of bearing	[ry]	1.952	mrاد (6.71')
Misalignment of bearing	[rz]	0.016	mrاد (0.05')
Misalignment of bearing	[rr]	0.048	mrاد (0.16')

Shaft 'Shaft 1' Bearing 'vstup'

Position (Y-coordinate)	[y]	0.00	mm
Bearing reaction force	[Fx]	0.000	kN
Bearing reaction force	[Fy]	0.000	kN
Bearing reaction force	[Fz]	0.000	kN
Bearing reaction force	[Fr]	0.000	kN
Bearing reaction moment	[Mx]	0.00	Nm
Bearing reaction moment	[My]	-4541.00	Nm
Bearing reaction moment	[Mz]	0.00	Nm
Bearing reaction moment	[Mr]	0.00	Nm (0°)
Displacement of bearing	[ux]	-0.005	mm
Displacement of bearing	[uy]	0.000	mm
Displacement of bearing	[uz]	-0.015	mm
Displacement of bearing	[ur]	0.016	mm (-108.16°)
Misalignment of bearing	[rx]	0.049	mrاد (0.17')
Misalignment of bearing	[ry]	0.000	mrاد (0')
Misalignment of bearing	[rz]	-0.016	mrاد (-0.05')
Misalignment of bearing	[rr]	0.051	mrاد (0.18')

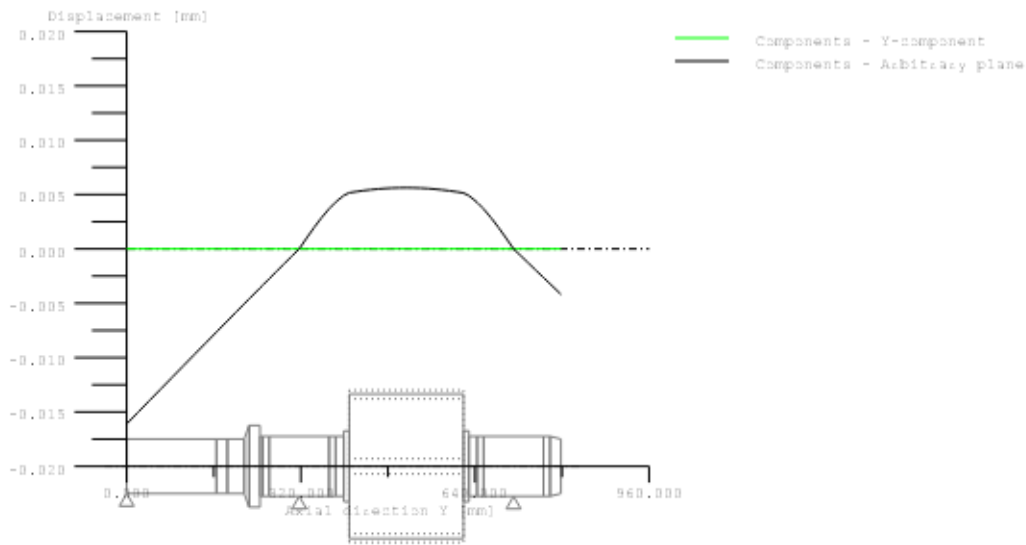
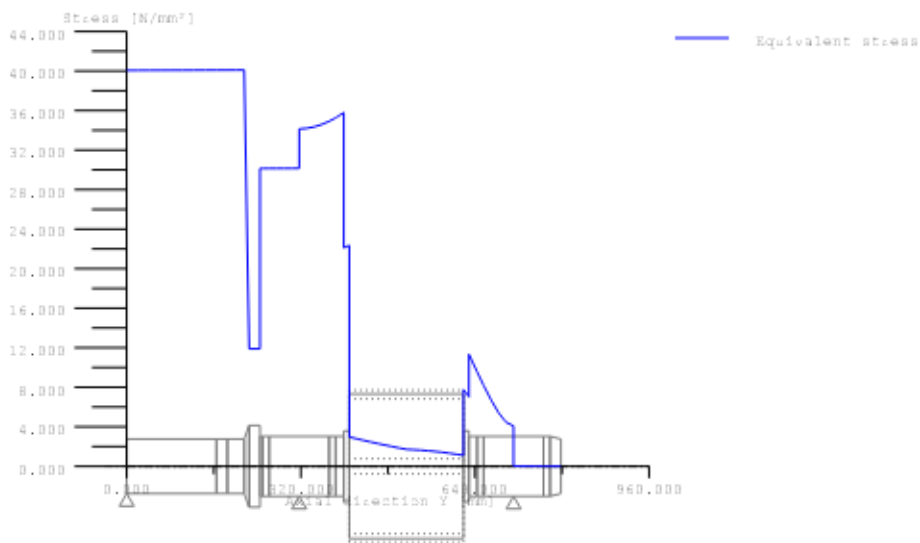


Figure: Displacement (bending etc.) (Arbitrary plane 71.83584776 °)



GEH(von Mises): $\text{sigV} = ((\text{sigB} + \text{sigZ}, D)^2 + 3 * (\text{tauT} + \text{tauS})^2)^{1/2}$

Figure: Equivalent stress

**Strength calculation as specified in
DIN 743:2000**

Summary

Label Shaft 1
Drawing

Material C45 (1)
Material type Through hardened steel
Material treatment unalloyed, through hardened
Surface treatment No

Calculation of endurance limit and the static strength
Calculation for load case 2 (sig.av/sig.mv = const)

Cross section	Position (Y-Coord) (mm)	
1	245.10	Smooth shaft
2	317.00	Smooth shaft
3	399.00	Own Input
4	629.00	Own Input
5	655.00	Smooth shaft
6	766.00	Smooth shaft

Results:

Cross section	Kfb	Kfsig	K2d	SD	SS
1	1.00	0.93	0.82	10.53	7.83
2	1.00	0.93	0.82	10.51	7.83
3	1.00	0.93	0.82	8.56	7.37
4	1.00	0.93	0.82	17.36	22.30
5	1.00	0.93	0.82	25.42	32.64
6	1.00	0.93	0.82	10000.00	10000.00

Nominal safety: 1.20 1.20

Abbreviations:

Kfb: Notch factor bending
Kfsig: Surface factor
K2d: Size coefficient bending
SD: Safety endurance limit
SS: Safety against yield point

The requirements of the safety proof of the shaft are:

satisfied [x] not satisfied []

Design engineer:..... Date:..... Signature:.....

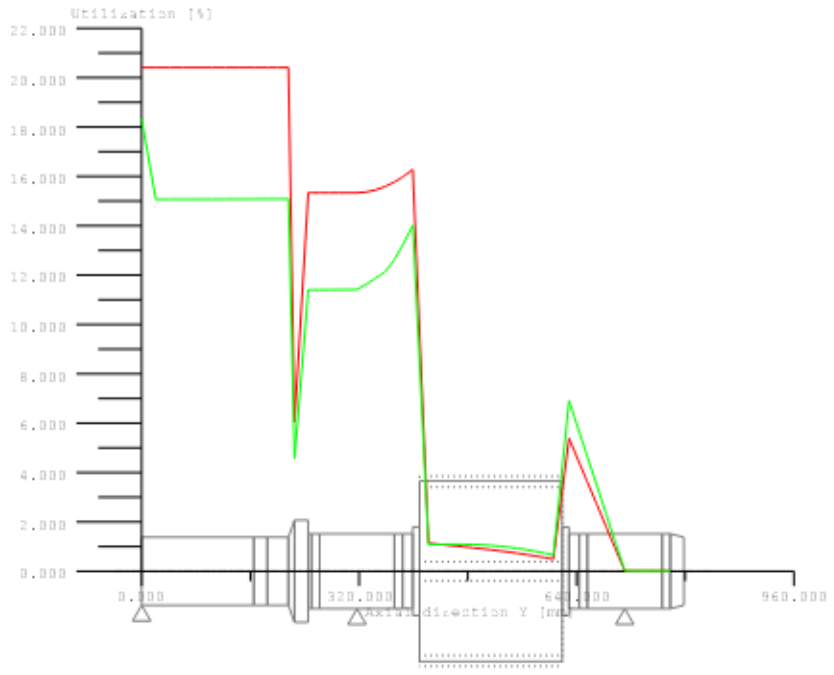


Figure: Strength

Calculation details:

General statements

Label		Shaft 1
Drawing		
Length (mm)	[l]	798.00
Speed (1/min)	[n]	1073.00
Material	C45 (1)	
Material type	Through hardened steel	
Material treatment	unalloyed, through hardened	
Surface treatment	No	

	Tension/Compression	Bending	Torsion	Shearing
Load factor static calculation	1.700	1.700	1.700	1.700
Load factor endurance limit	1.000	1.000	1.000	1.000

Reference diameter material (mm)	[dB]	16.00
sigB according DIN 743 (at dB) (N/mm ²)	[sigB]	700.00
sigS according DIN 743 (at dB) (N/mm ²)	[sigS]	490.00
[sigzdW] (bei dB) (N/mm ²)		280.00
[sigbW] (bei dB) (N/mm ²)		350.00
[tautW] (bei dB) (N/mm ²)		210.00
Thickness of raw material (mm)	[dWerkst]	270.00
Material data calculated according DIN743/3 with Kl(d)		
Material strength calculated from size of raw material		
Geometric size coefficient Kl(d) calculated from raw material diameter		
[sigBeff] (N/mm ²)		476.64
[sigSeff] (N/mm ²)		333.65
[sigbF] (N/mm ²)		400.38
[tautF] (N/mm ²)		231.16

[sigzdW] (N/mm ²)	190.66
[sigbW] (N/mm ²)	238.32
[tautW] (N/mm ²)	142.99

Endurance limit for single stage use

Calculation for load case 2 (sig.av/sig.mv = const)

Cross section '1' Smooth shaft

Comment

Position (Y-Coordinate) (mm)	[y]	245.10
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	18.3	2270.5	166.3
Maximum value	-0.0	31.2	7719.7	282.7
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.140	8.688	0.023
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.239	29.539	0.040

Technological size influence	[K1 (sigB)]	0.681
	[K1 (sigS)]	0.681

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821
Influence coefficient surface roughness	[KF]	0.925	0.957
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.081	1.299

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	176.370	183.399	113.173
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.227	0.238	0.135
Permissible amplitude (N/mm ²)	[sigADK]	0.022	3.702	99.737
Margin of safety endurance limit	[S]		10.525	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		877.1	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	333.649	400.379	231.159
Margin of safety yield stress	[S]		7.826	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		652.1	

Cross section '2' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	317.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	2270.5	0.0
Amplitude	0.0	32.2	2270.5	213.8
Maximum value	-0.0	54.7	7719.7	363.4
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.246	8.688	0.030
[sigzdmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.419	29.539	0.051

Technological size influence	[K1 (sigB)]	0.681
	[K1 (sigS)]	0.681

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.925	0.925	0.957
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.081	1.299	1.263

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	176.370	183.399	113.173
Influence coeff. mean stress sensitivity.	[PsisigK]	0.227	0.238	0.135
Permissible amplitude (N/mm ²)	[sigADK]	0.022	6.447	99.737
Margin of safety endurance limit	[S]	10.514		
Required safety	[Smin]	1.200		
Result (%)	[S/Smin]	876.1		

Present margin of safety for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	333.649	400.379	231.159
Margin of safety yield stress	[S]	7.825		
Required safety	[Smin]	1.200		
Result (%)	[S/Smin]	652.1		

Cross section '3' Own Input

Comment		
Position (Y-Coordinate) (mm)	[y]	399.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Own Input		
Mean roughness (µm)	[Rz]	8.000

		Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)					
Mean value		-0.0	0.0	2270.5	0.0
Amplitude		0.0	1396.5	2270.5	16683.6
Maximum value		-0.0	2374.1	7719.7	28362.2
Cross section, moment of resistance: (mm ²)					
[A, Wb, Wt, A]		9503.3	130671	261341	9503.3

Stresses: (N/mm ²)					
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	8.688	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	10.687	8.688	2.341
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	18.169	29.539	3.979

Technological size influence	[K1 (sigB)]	0.681
	[K1 (sigS)]	0.681

		Tension/Compression	Bending	Torsion
Notch effect coefficient [dB] (mm) = 0.0	[beta (dB)]	0.000	0.000	0.000
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.925	0.925	0.957
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.081	1.299	1.263

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]	15.048		
Equivalent mean stress (N/mm ²)	[taumV]	8.688		
Fatigue limit of part (N/mm ²)	[sigWK]	176.370	183.399	113.173
Influence coeff. mean stress sensitivity.	[PsisigK]	0.227	0.238	0.135
Permissible amplitude (N/mm ²)	[sigADK]	0.022	137.336	99.737
Margin of safety endurance limit	[S]	8.561		

Required safety	[Smin]	1.200		
Result (%)	[S/Smin]	713.4		
Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	333.649	400.379	231.159
Margin of safety yield stress	[S]		7.374	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		614.5	

Cross section '4' Own Input

Comment				
Position (Y-Coordinate) (mm)	[y]		629.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Own Input				
Mean roughness (µm)	[Rz]		8.000	
Tension/Compression Bending Torsion Shearing				
Stress: (N) (Nm)				
Mean value		-0.0	0.0	0.0 0.0
Amplitude		0.0	1380.3	0.0 16835.0
Maximum value		-0.0	2346.4	0.0 28619.5
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]		9503.3	130671	261341 9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)		-0.000	0.000	0.000 0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)		0.000	10.563	0.000 2.362
[sigzdm, sigbmax, taumax, tauqmax] (N/mm ²)		-0.000	17.957	0.000 4.015

Technological size influence	[K1 (sigB)]		0.681	
	[K1 (sigS)]		0.681	

Tension/Compression Bending Torsion				
Notch effect coefficient	[beta (dB)]	0.000	0.000	0.000
[dB] (mm) = 0.0				
Geometrical size influence	[K3 (d)]	0.000	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.925	0.925	0.957
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.081	1.299	1.263

Present margin of safety for endurance limit:				
Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	176.370	183.399	113.173
Influence coeff. mean stress sensitivity.				
	[PsisigK]	0.227	0.238	0.135
Permissible amplitude (N/mm ²)	[sigADK]	176.370	183.399	113.173
Margin of safety endurance limit	[S]		17.363	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1446.9	

Present margin of safety for proof against exceed of yield point:				
Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	333.649	400.379	231.159
Margin of safety yield stress	[S]		22.297	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		1858.1	

Cross section '5' Smooth shaft

Comment				
Position (Y-Coordinate) (mm)	[y]		655.00	
External diameter (mm)	[da]		110.000	
Inner diameter (mm)	[di]		0.000	
Notch effect Smooth shaft				
Mean roughness (µm)	[Rz]		8.000	

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	942.9	0.0	16816.1
Maximum value	-0.0	1602.9	0.0	28587.3
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	7.216	0.000	2.359
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	12.267	0.000	4.011

Technological size influence	[K1 (sigB)]	0.681
	[K1 (sigS)]	0.681

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000
Notch effect coefficient	[beta]	1.000	1.000
Geometrical size influence	[K2 (d)]	1.000	0.821
Influence coefficient surface roughness	[KF]	0.925	0.925
Influence coefficient surface strengthening	[KV]	1.000	1.000
Total influence coefficient	[K]	1.081	1.299

Present margin of safety for endurance limit:			
Equivalent mean stress (N/mm ²)	[sigmV]	0.000	
Equivalent mean stress (N/mm ²)	[taumV]	0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	176.370	183.399
Influence coeff. mean stress sensitivity.			
	[PsisigK]	0.227	0.238
Permissible amplitude (N/mm ²)	[sigADK]	176.370	183.399
Margin of safety endurance limit	[S]	25.416	
Required safety	[Smin]	1.200	
Result (%)	[S/Smin]	2118.0	

Present margin of safety for proof against exceed of yield point:			
Static notch sensitivity factor	[K2F]	1.000	1.200
Increase coefficient	[gammaF]	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	333.649	400.379
Margin of safety yield stress	[S]	32.638	
Required safety	[Smin]	1.200	
Result (%)	[S/Smin]	2719.9	

Cross section '6' Smooth shaft

Comment		
Position (Y-Coordinate) (mm)	[y]	766.00
External diameter (mm)	[da]	110.000
Inner diameter (mm)	[di]	0.000
Notch effect Smooth shaft		
Mean roughness (µm)	[Rz]	8.000

	Tension/Compression	Bending	Torsion	Shearing
Stress: (N) (Nm)				
Mean value	-0.0	0.0	0.0	0.0
Amplitude	0.0	0.3	0.0	27.1
Maximum value	-0.0	0.6	0.0	46.1
Cross section, moment of resistance: (mm ²)				
[A, Wb, Wt, A]	9503.3	130671	261341	9503.3

Stresses: (N/mm ²)				
[sigzdm, sigbm, taum, tauqm] (N/mm ²)	-0.000	0.000	0.000	0.000
[sigzda, sigba, taua, tauqa] (N/mm ²)	0.000	0.003	0.000	0.004
[sigzdmmax, sigbmax, taumax, tauqmax] (N/mm ²)	-0.000	0.004	0.000	0.006

Technological size influence	[K1 (sigB)]	0.681
	[K1 (sigS)]	0.681

	Tension/Compression	Bending	Torsion
Notch effect coefficient	[beta (dB)]	0.000	0.000
[dB] (mm) = 0.0			
Geometrical size influence	[K3 (d)]	0.000	0.000
Geometrical size influence	[K3 (dB)]	0.000	0.000

Notch effect coefficient	[beta]	1.000	1.000	1.000
Geometrical size influence	[K2(d)]	1.000	0.821	0.821
Influence coefficient surface roughness	[KF]	0.925	0.925	0.957
Influence coefficient surface strengthening	[KV]	1.000	1.000	1.000
Total influence coefficient	[K]	1.081	1.299	1.263

Present margin of safety for endurance limit:

Equivalent mean stress (N/mm ²)	[sigmV]		0.000	
Equivalent mean stress (N/mm ²)	[taumV]		0.000	
Fatigue limit of part (N/mm ²)	[sigWK]	176.370	183.399	113.173
Influence coeff. mean stress sensitivity.	[PsigK]	0.227	0.238	0.135
Permissible amplitude (N/mm ²)	[sigADK]	176.370	183.399	113.173
Margin of safety endurance limit	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Present margin of safety

for proof against exceed of yield point:

Static notch sensitivity factor	[K2F]	1.000	1.200	1.200
Increase coefficient	[gammaF]	1.000	1.000	1.000
Yield stress of part (N/mm ²)	[sigFK]	333.649	400.379	231.159
Margin of safety yield stress	[S]		10000.000	
Required safety	[Smin]		1.200	
Result (%)	[S/Smin]		10000.0	

Remarks:

- The shearing force is not considered in the analysis according to DIN 743..
- Cross section with square groove:
The reference diameter for the notch number is not defined.
Therefore the shaft diameter is taken as reference diameter..
- Cross section with interference fit:
The notching factor for the light fit case is no longer defined in DIN 743.
The values are imported from the FKM-Guideline..

End report

lines: 710

Příloha 4: specifikace asynchronního motoru

TROJFÁZOVÉ ASYNCHRONNÍ ELEKTROMOTORY

VELIKOST 355 - 500

THREE-PHASE INDUCTION MOTORS

SIZE 355 - 500

TECHNICKÁ DATA TECHNICAL DATA

400/690V, 50Hz - motory velikosti (for motors frame size) 355, 400
690V, 50 Hz - motory velikosti (for motors frame size) 450, 500

Pol. Item	Typ Motor type	Jmenovitý výkon Rated power	Otáčky Speed	Jmenovitý proud Rated current	Účinník Power factor	Účinnost Efficiency	Rozběhový proud Starting current	Rozběhový moment Starting torque	Moment zvratu Breakdown torque	Moment setrvačnosti Moment of inertia	Hmotnost Mass	Akustický tlak Sound pressure level
		P_N	n_N	I_N	$\cos\varphi$	η	I/I_N	T_I/T_N	T_b/T_N	J	m	$Ld_1(A)$
		kW	rpm	A	-	%	-	-	-	kgm ²	kg	dB(A)

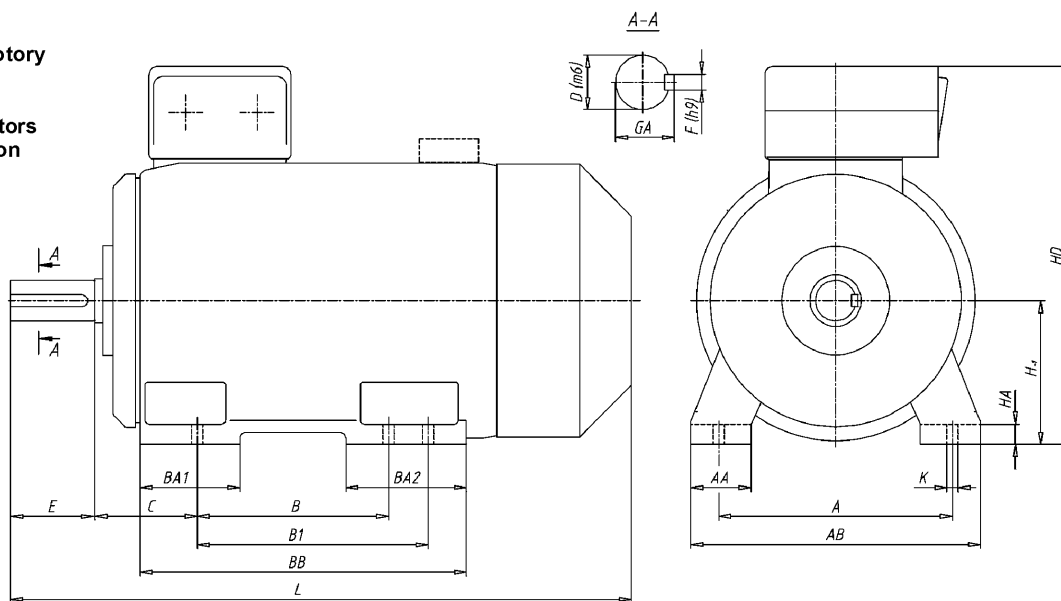
3000 rpm (2p=2)	SEE 355 ML2A	250	2982	415/240	0,91	96,4/96,3/95,5	7,0	1,8	2,8	2,7	1530	83
	SEE 355 ML2B	280	2981	461/266	0,91	96,4/96,4/95,6	6,8	1,7	2,8	3,3	1680	83
	SEE 355 ML2B	315	2982	517/299	0,91	96,6/96,6/95,9	7,3	1,9	3,0	3,3	1680	83
	Sh 355 H2Ds	355	2985	584/337	0,91	96,5/96,3/95,5	7,4	1,7	2,7	4,9	2140	83
	Sh 355 H2Es	400	2985	656/379	0,91	96,7/96,6/95,5	7,5	1,6	2,8	5,3	2200	83
	Sh 400 H2Cs	450	2983	741/428	0,91	96,5/96,3/95,5	6,6	1,3	2,6	6,5	2700	84
	Sh 400 H2Ds	500	2985	821/474	0,91	96,6/96,5/95,8	7,2	1,4	2,8	7,3	2800	84
	Sh 400 H2Es	560	2989	927/535	0,90	96,9/96,7/95,9	8,0	1,7	3,0	8,6	3000	84
	Sh 400 H2Es	600	2984	973/562	0,92	96,9/96,8/96,0	8,0	1,6	2,9	8,6	3000	84

1500 rpm (2p=4)	SEE 355 ML4A	250	1489	424/245	0,89	96,3/96,4/95,8	7,3	2,0	2,4	4,9	1610	78
	SEE 355 ML4AB	285	1487	477/275	0,90	96,3/96,4/96,0	7,4	2,0	2,3	5,6	1710	78
	SEE 355 ML4B	315	1489	523/302	0,90	96,6/96,7/96,4	7,6	2,2	2,5	6,2	1810	78
	SEE 355 ML4BB	330	1488	555/321	0,89	96,5/96,6/96,2	7,5	2,0	2,4	6,2	1810	78
	Sh 355 H4Ds	355	1488	604/349	0,88	96,5/96,7/96,3	6,5	1,6	2,2	8,2	2190	84
	Sh 355 H4Es	400	1489	678/392	0,88	96,7/96,8/96,4	7,0	1,8	2,3	9,1	2320	84
	Sh 400 H4Cs	450	1490	762/440	0,88	96,9/96,9/96,3	7,6	1,6	2,6	12,3	2920	82
	Sh 400 H4Ds	500	1491	856/495	0,86	97,0/97,0/96,5	7,5	1,6	2,5	13,6	3100	82
	Sh 400 H4Es	560	1491	959/554	0,87	97,0/97,0/96,6	7,6	1,7	2,6	15,0	3220	82
	Sh 400 H4Fs	630	1491	1076/621	0,87	97,1/97,1/96,7	8,4	1,9	2,8	16,5	3370	83
	Sh 450 H4Bs	710	1492	696	0,88	97,1/97,1/96,6	7,0	1,0	2,5	27,1	4000	84
	Sh 450 H4Cs	800	1493	774	0,89	97,1/97,1/96,8	6,8	1,0	2,6	30,8	4240	84
	Sh 450 H4Ds	900	1493	881	0,88	97,2/97,2/96,8	7,3	1,0	2,5	34,4	4460	84
	Sh 450 H4Es	1000	1493	966	0,89	97,3/97,3/96,8	7,3	1,0	2,5	38,0	4700	84
	Sh 500 H4Cs	1120	1494	1095	0,88	97,4/97,4/96,9	6,5	0,8	2,4	58,4	6100	84
	Sh 500 H4Ds	1250	1494	1220	0,88	97,5/97,5/96,9	6,5	0,8	2,4	65,2	6600	84
Sh 500 H4Es	1400	1494	1367	0,88	97,5/97,5/96,9	6,6	0,8	2,4	72,2	6900	84	

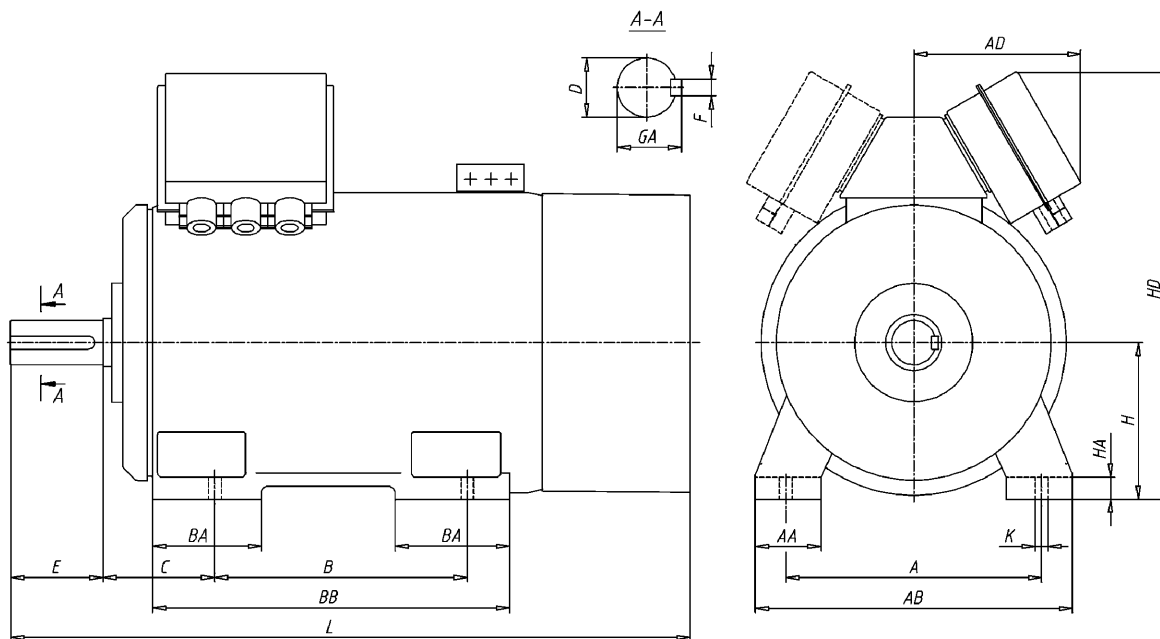
**ROZMĚRY
DIMENSIONS**

Patkové elektromotory
tvar IM1001 (B3)

Foot-mounted motors
type of construction
IM1001 (B3)



Typ Type	2p	A	B	B1	C	D	E	F	GA	H	HA	K	AA	AB	BA1	BA2	BB	HD	L
SEE 355	2	610	560	630	254	80	170	22	85	355	50	28	150	720	250	300	890	935	1580
SEE 355	4+8	610	560	630	254	100	210	28	106	355	50	28	150	720	250	300	890	935	1620
Sh 355...s	2	610	900	-	200	70	140	20	74.5	355	45	28	160	730	265	265	1045	995	1800
Sh 355...s	4+8	610	900	-	200	100	210	28	106	355	45	28	160	730	265	265	1045	995	1870



Typ Type	2p	A	B	C	D	E	F	GA	H	HA	K	AA	AB	AD	BA	BB	HD	L
Sh 400...s	2	686	1000	224	80	170	22	85	400	50	35	175	840	520	265	1160	1255	1980
Sh 400...s	4+8	686	1000	224	110	210	28	116	400	50	35	175	840	520	265	1160	1255	1960
Sh 450...s	2	750	1120	450	80	170	22	85	450	60	35	205	940	560	340	1320	1356	2410
Sh 450...s	4+10	750	1120	254	110	210	28	116	450	60	35	205	940	560	340	1320	1356	2090
Sh 500...s	4+10	850	1250	280	120	210	32	127	500	70	42	223	1050	560	300	1450	1470	2430

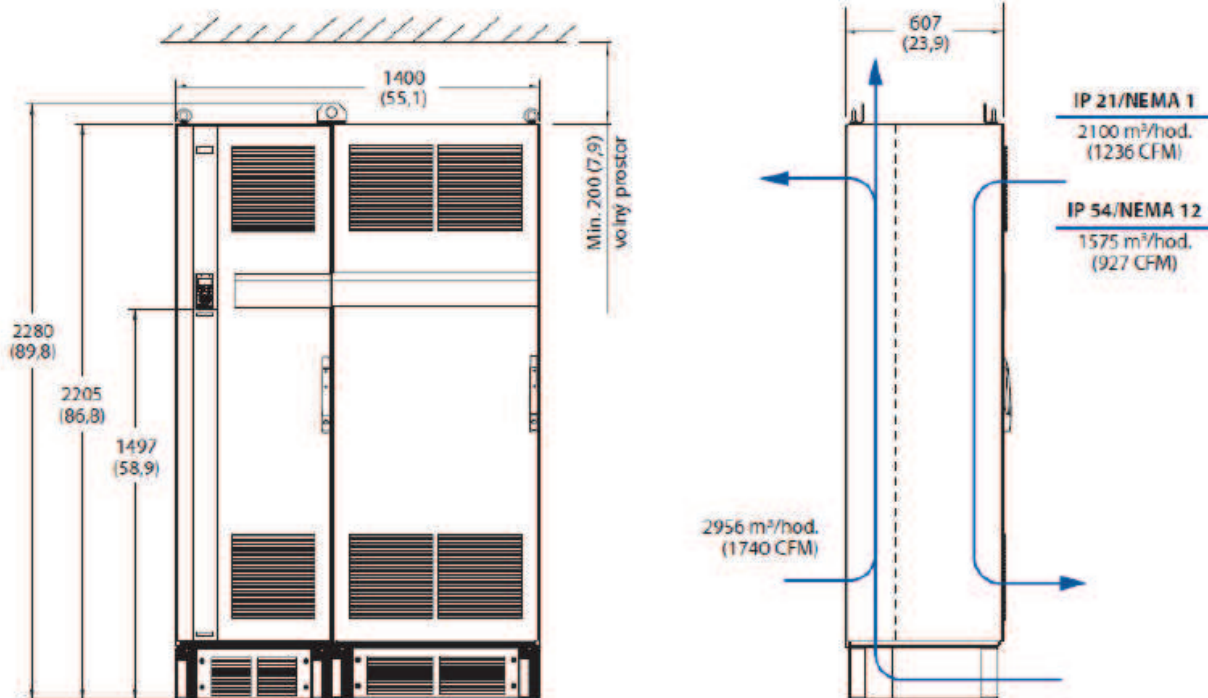
Příloha 5: specifikace frekvenčního měniče

Popis produktů

Pozice	Objednáací číslo	Popis
10	300_SER	FC-302P630T5E21H2XGCXXXSXXXXXAXBXCXXXXDX
		<p>Jm. Výkon měniče při dodání 550 kW</p> <p>Jm. Proud měniče při dodání 990 A</p> <p>Jm. výkon/110% moment. přetížitelnost 710 kW</p> <p>Jm. proud/110% proud. přetížitelnost 1260 A</p> <p>Typová řada VLT® AutomationDrive</p> <p>Varianta FC-302 AutomationDrive Rozšíř.</p> <p>Jmenovitý výkon 630 KW</p> <p>Počet fází Trojfázový</p> <p>Jmenovité napájení 380 - 500 VAC</p> <p>Enclosure IP21 / Type 1</p> <p>RFI filtr RFI filtr třídy A2</p> <p>Brzdný střídač, Safe Stop Bez brzdného střídače</p> <p>Ovládací panel Grafický ovládací panel</p> <p>Přídavné lakování S přídavným lakov. ploš. spojů</p>

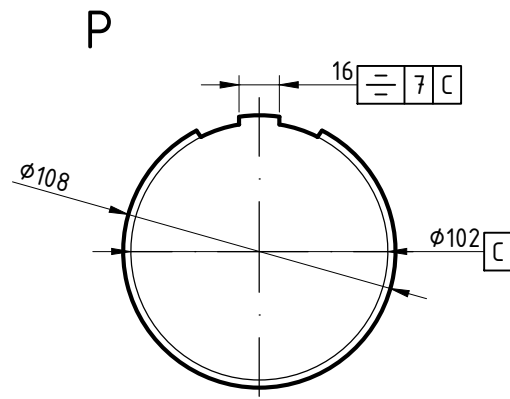
Skříň F1 (montáž na podlahu)

mm (palce)



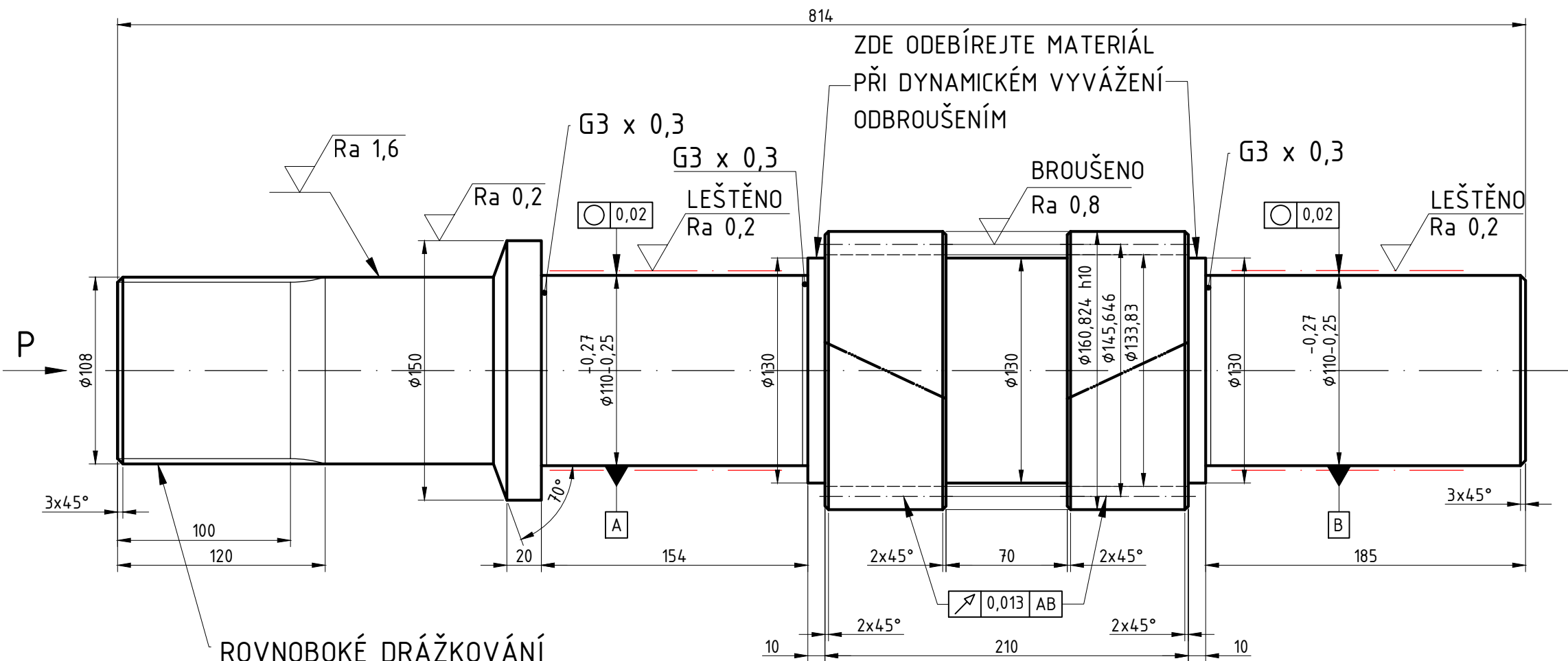
Příloha 6: výkresová dokumentace

(obsahuje výrobní výkres pomaloběžného hřídele a sestavu celé pomocné převodovky)



$\sqrt{Ra\ 3,2}$ ($\sqrt{Ra\ 1,6}$ $\sqrt{Ra\ 0,8}$ $\sqrt{Ra\ 0,2}$)

Modul	m	6	
Počet zubů	z	22	
Normální základní profil	-	ČSN 01 4607	
Úhel sklonu boční křivky zubu	β	25°	
Smysl stoupání boční křivky zubů	-	levý/pravý	
Jednotkové posunutí	x	0,2654	
Stupeň přesnosti podle	-	ČSN 01 4682	
Kontrolované mezní úchytky	dvoubokého odvalu za otáčku	F_i''	-
	dvoubokého odvalu za rozteč	f_i''	-
	sklonu zubů	F_β	-
	vzdálenosti os	F_a	-
Spoluzabírající kolo	číslo výkresu	-	-
	počet zubů	z	73
	vzdálenost os	a	315
Modul	m	6,62	
Počet zubů hřebenu, segmentu	z	-	
Průměr základní kružnice	d_b	135,154	
Průměr roztečné kružnice	d	145,646	
Průměr patní kružnice	d_f	133,83	
Úhel sklonu boční křivky zubů na základním válci	β	-	
Úhel os	Σ	-	



ROVNOBOKÉ DRÁŽKOVÁNÍ
10 x 102g7 x 108a11 x 16f9

0,015 AB

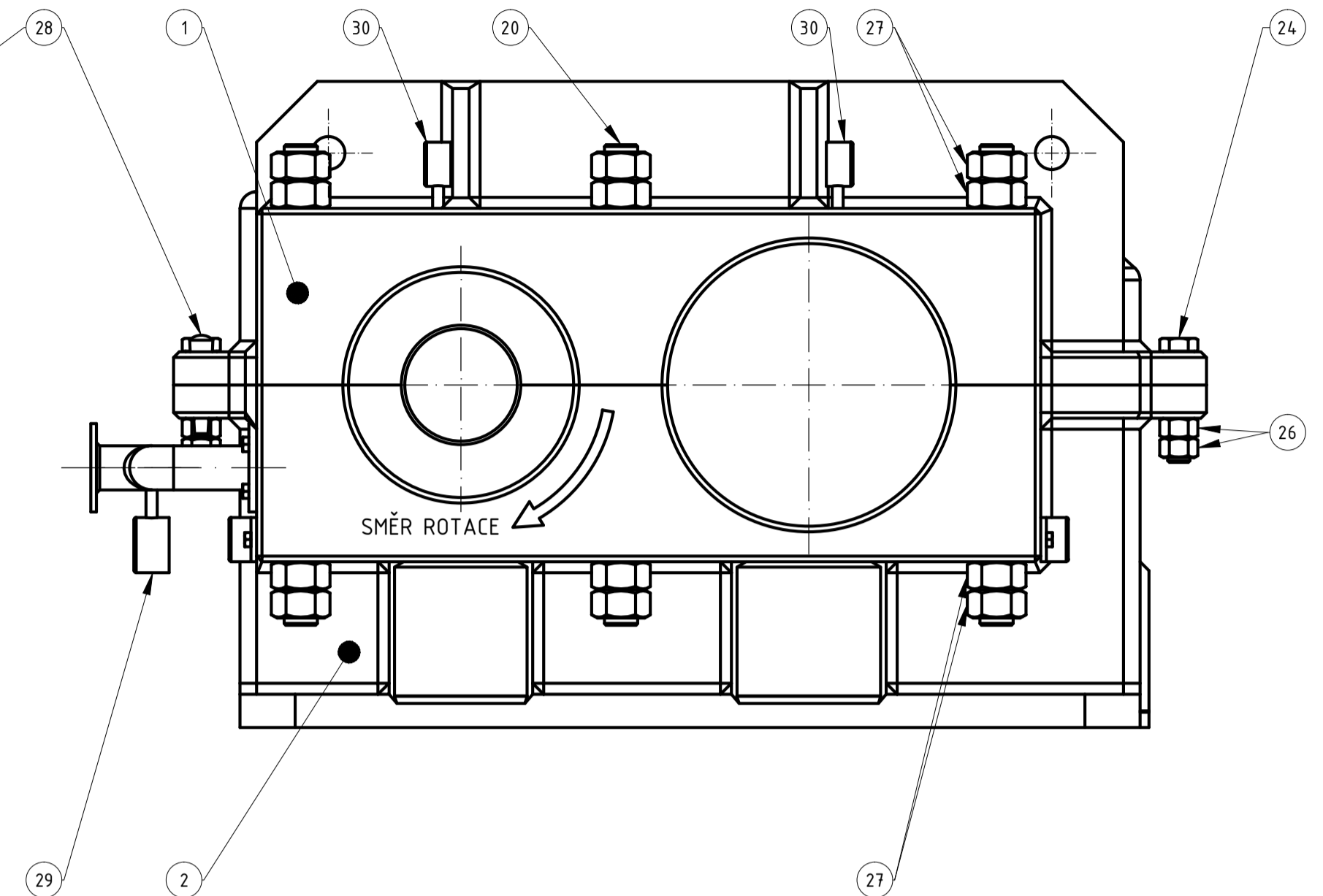
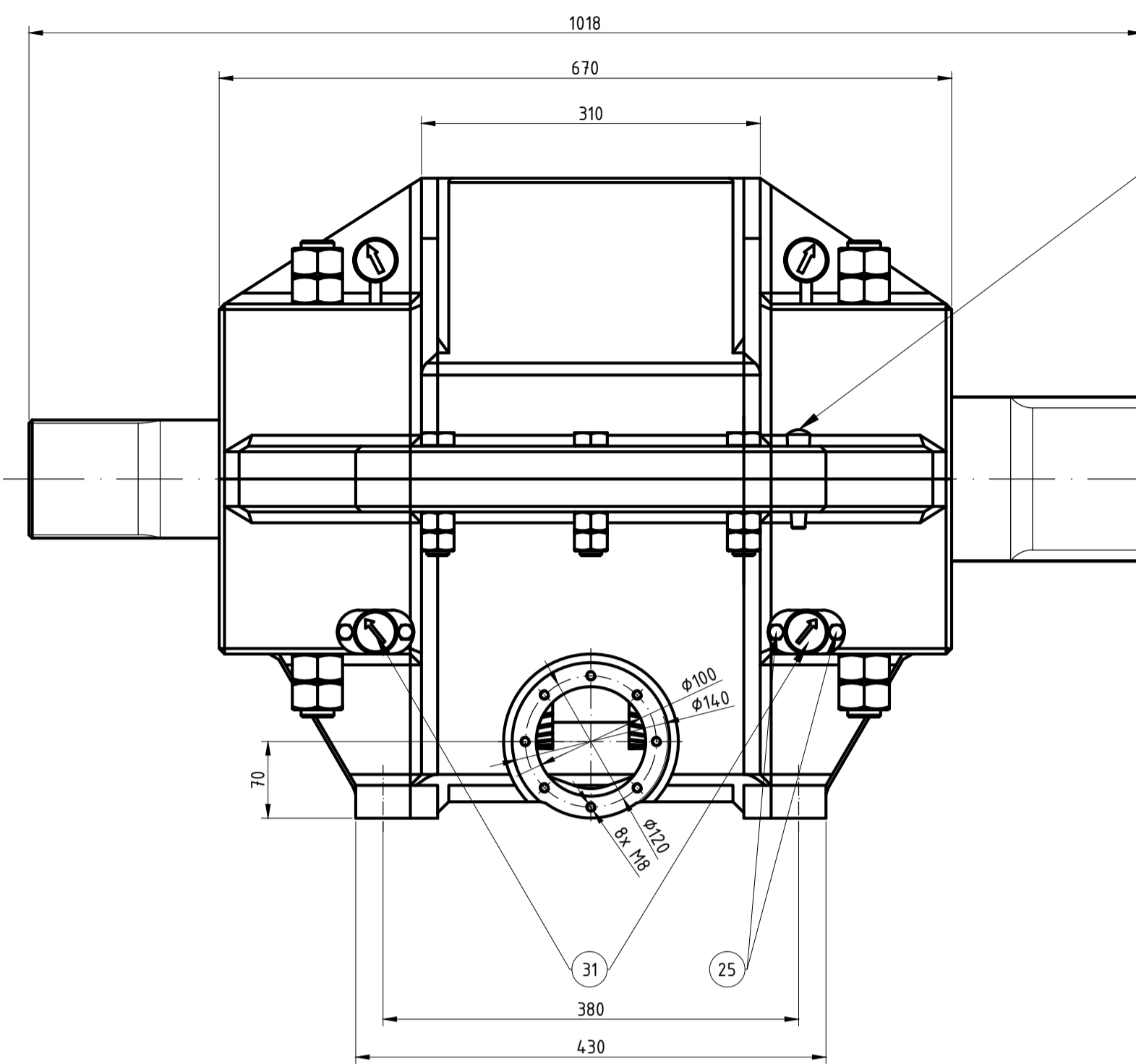
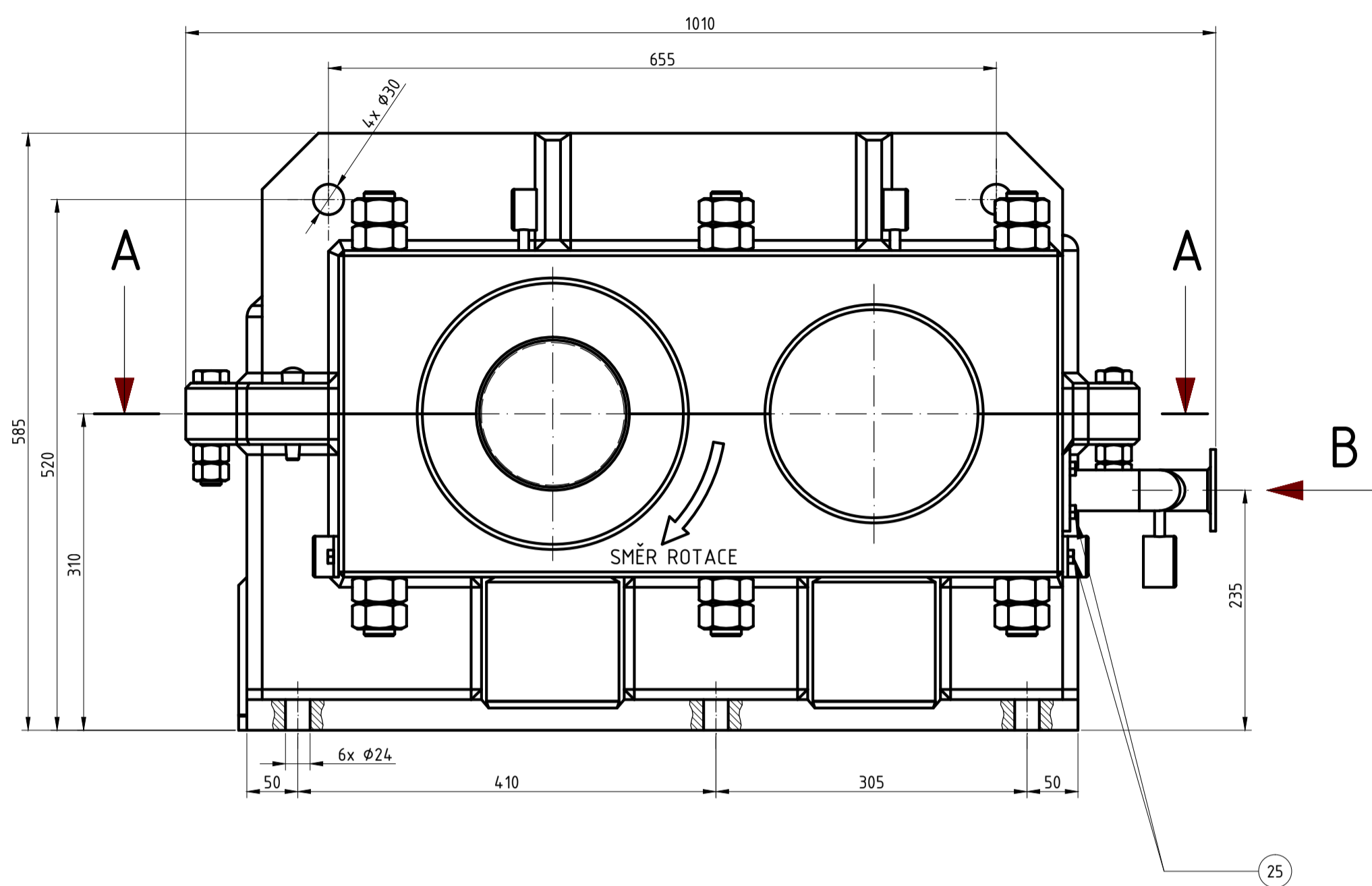
ZDE ODEBÍREJTE MATERIÁL
PŘI DYNAMICKÉM VYVÁŽENÍ
ODBROUŠENÍM

BROUŠENO
Ra 0,8

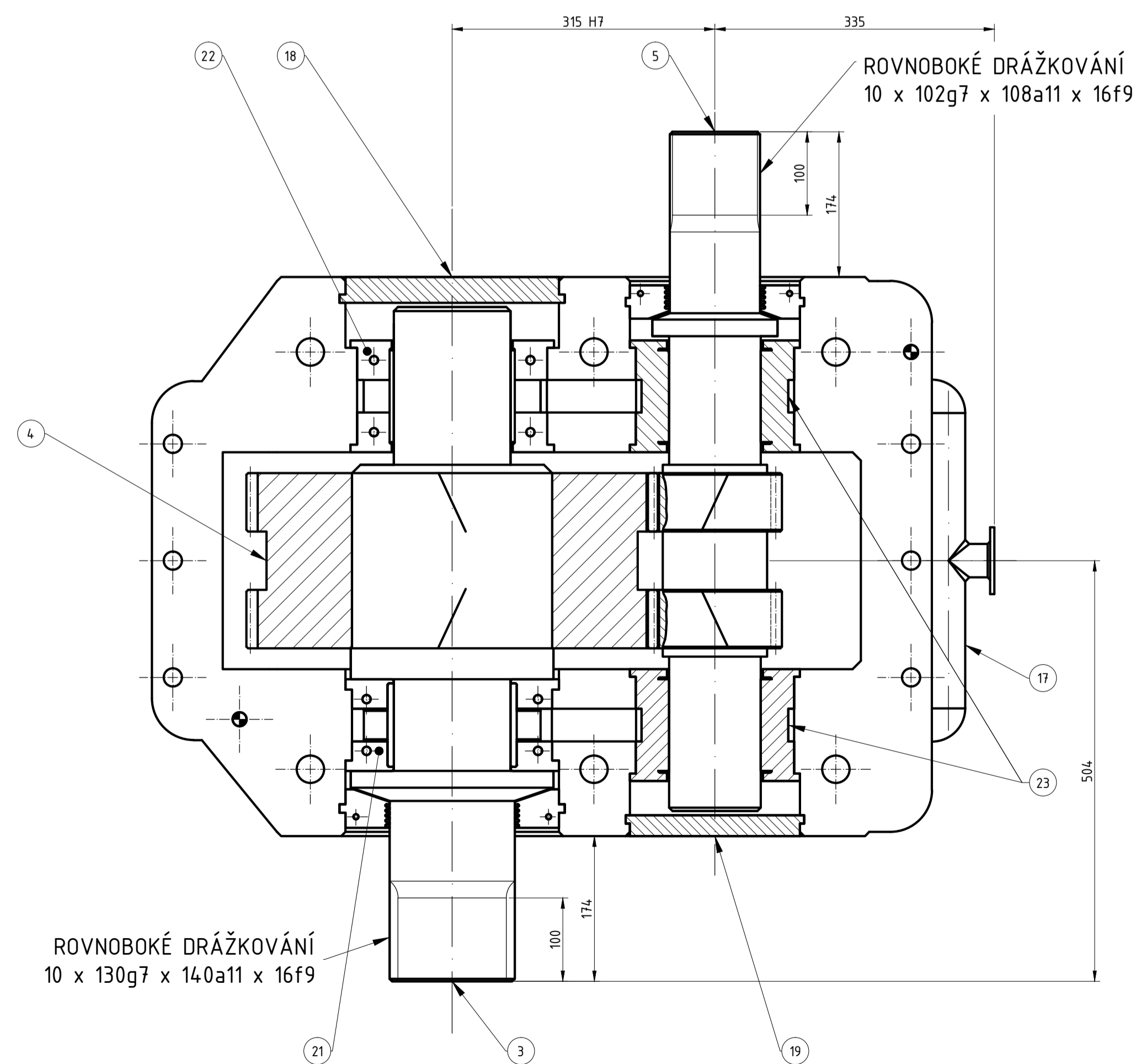
LEŠTĚNO
Ra 0,2

CEMENTOVÁNO h 0,8-1 [mm] A KALENO HRC 58-62

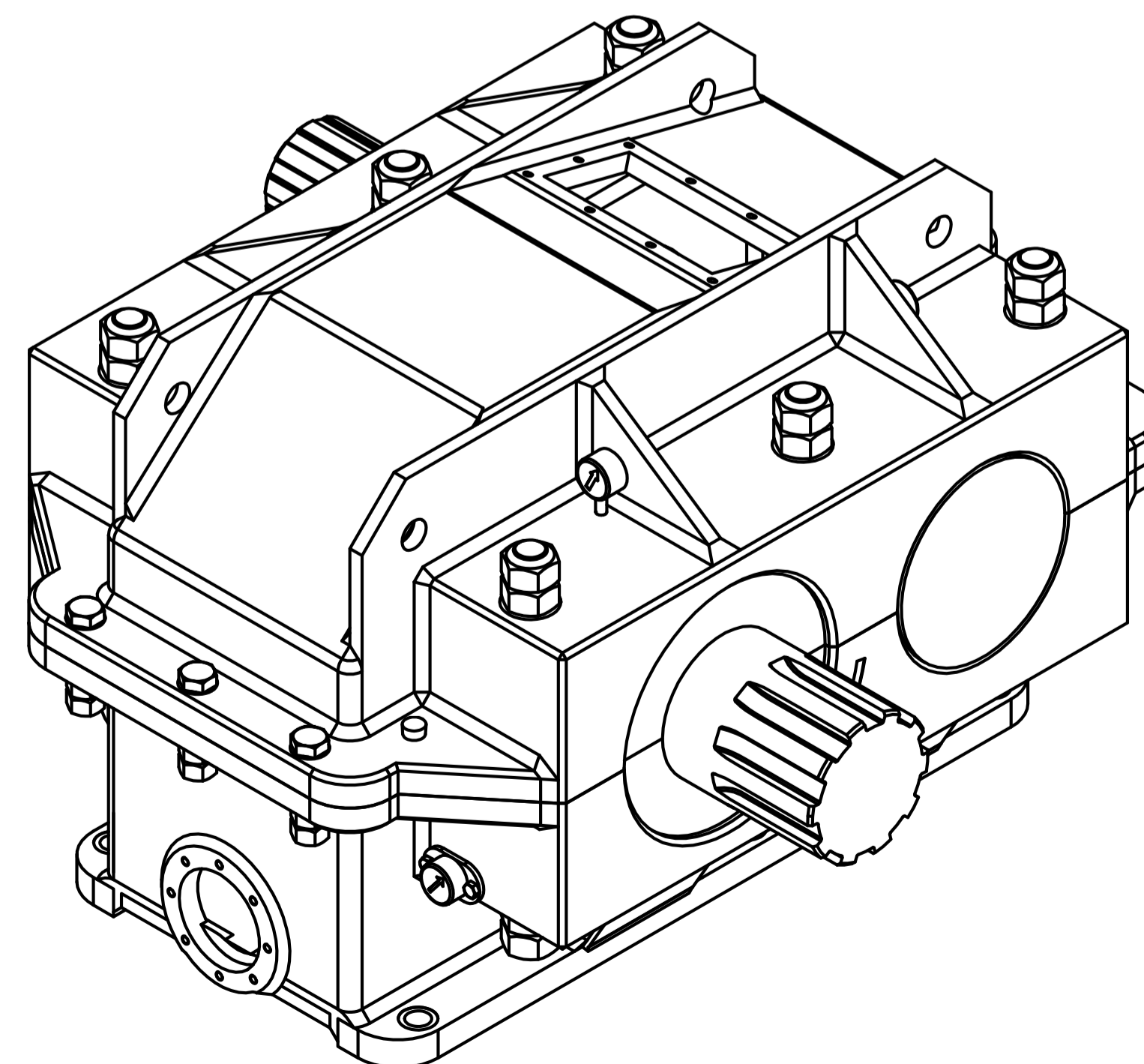
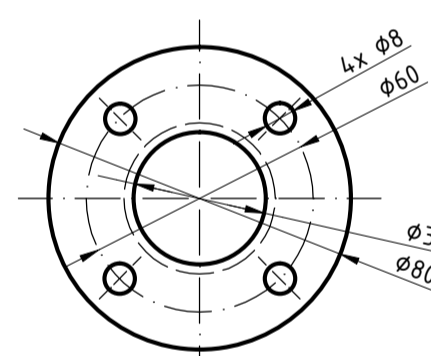
PROMÍTÁNÍ	MĚŘÍTKO	PŘESNOST ISO 2768 - mK	HMOTNOST	INDEX	ZMĚNA	
	1:3	TOLEROVÁNÍ ISO 8015	75 Kg			
 FAKULTA STROJNÍ ZÁPADOČESKÉ UNIVERSITY V PLZNI KATEDRA KONSTRUOVÁNÍ STROJŮ		MATERIÁL		ROZMĚR - POLOTOVAR		
		42 CrMo 4 MQ		42 CrMo 4 VÝKOVEK		
		KRESLIL	Bc. JIŘÍ ŠUCH	DATUM	23.5.2014	ČÍSLO VÝKRESU SESTAVY
		TECH.REFERENT		DATUM		DP-SESTAVA
SCHVÁLIL		DATUM		ČÍSLO SEZNAMU POLOŽEK		
NÁZEV			ISO 16016	TYP DOKUMENTU		
HŘÍDEL 2			ČÍSLO VÝKRESU	VÝROBNÍ VÝKRES		
			DP-HŘÍDEL 2			
LISTŮ/LIST 1/1						



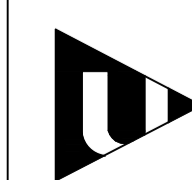
A-A



B (1:2)



POZ.	NÁZEV - ROZMĚR POLOTOVAR	ČÍSLO VÝKRESU ČÍSLO NORMY	MATERIÁL	HMOTNOST JEDNOTKA	MN.
31	TEPLOMĚR ŠIKMÝ			2	4
30	TEPLOMĚR PŘÍMÝ			2	4
29	MANOMETR			1	1
28	KOLÍK 12x85	ISO 2339		0,1	2
27	MATICE M30	ISO 24032		0,25	24
26	MATICE M20	ISO 24032		0,2	12
25	ŠROUB M8x16	ISO 4014-8,8		0,1	16
24	ŠROUB M20x100	ISO 4014-10,9		0,3	6
23	TF 110x110	WAUKESHA BEARINGS		16	2
22	LOŽISKO RADIÁLNÍ			26	1
21	LOŽISKO RADIÁLNĚ-AXIÁLNÍ			21,5	1
20	SVORNÍK M30x435		17 248	2,4	6
19	VÍKO 2		11 373	6,6	1
18	VÍKO 1		11 373	13	1
17	OLEJOVOD		11 343	1,9	1
16	KOLO 8		42 CrMo 4	85	1
15	HŘÍDEL 8		C45 (1)	65	1
14	KOLO 7		42 CrMo 4	140	1
13	HŘÍDEL 7		C45 (1)	119	1
12	KOLO 6		42 CrMo 4	53	1
11	HŘÍDEL 6		C45 (1)	65	1
10	KOLO 5		42 CrMo 4	187	1
9	HŘÍDEL 5		C45 (1)	119	1
8	HŘÍDEL 4		42 CrMo 4	89	1
7	KOLO 3		42 CrMo 4	215	1
6	HŘÍDEL 3		C45 (1)	142	1
5	HŘÍDEL 2	DP-HŘÍDEL 2	42 CrMo 4	75	1
4	KOLO 1		42 CrMo 4	239	1
3	HŘÍDEL 1		C45 (1)	166	1
2	SPODNÍ DÍL SKŘÍNĚ		11 373	361	1
1	VRCHNÍ DÍL SKŘÍNĚ		11 373	323	1


 FAKULTA STROJNÍ
ZÁPADOČESKÉ
UNIVERSITY
V PLZNI

KATEDRA KONSTRUOVÁNÍ STROJŮ

PROMĚTÁNÍ: 1:5
 MĚŘÍTKO: 1:5
 CELKOVÁ HMOTNOST: 1310 Kg
 ZMĚNA 1: 23.5.2014
 ZMĚNA 2:

REKONSTRUOVANÉ
 Bc. JIŘÍ ŠUCH

TECHNICKÝ REFERENT: Bc. JIŘÍ ŠUCH
 DATUM: 23.5.2014
 ČÍSLO VÝKRESU SESTAVY:

SCHVÁLIL:

NÁZEV: SESTAVA
 ČÍSLO VÝKRESU: DP-SESTAVA
 TYP DOKUMENTU: SESTAVA
 ČÍSLO SEZNAMU POLOŽEK:

ISO 16016
 TYP DOKUMENTU: SESTAVA

LISTUJÍCÍ 1/1