ZPĚT

ANALYSIS OF SOME ASPECTS OF SURFACE INTEGRITY AFTER GRINDING AND HARD TURNING

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This paper deals with the application of Barkhausen noise for investigation of residual stresses after turning and grinding. Results illustrate the differences in stress distribution after turning and grinding. The analysis of stress state shows that Barkhausen noise can be easily applied to the identification of thermal load and therefore for monitoring of a grinding process. On the other hand, the conventional evaluation of Barkhausen noise fail and monitoring of surface integrity will require a subsequent modified approach. The main reason for it is a more complicated relationship between stresses, surface hardness and structure.

Key words: Barkhausen noise, residual stress, grinding, turning

1 Introduction

Investigation of residual stresses in surface can be carried out through the many methods. X-ray diffraction, ultrasound methods and micromagnetic methods are non destructive methods for evaluation of surfaces. On the other hand, mechanical method is destructive. Each of these methods has some advantages and disadvantages.

The continuous rotation of magnetic field results in a non continuous magnetization Bloch Wall (BW) rotation. This discontinuity is called Barkhausen noise. An increasing density of elastic energy leads to a change in domains shape in order to minimize internal energy (in the case of ferromagnetic materials). This reaction is called a magneto elastic response to a mechanically induced stress. An external tensile load results into increasing domains that are parallel with the direction of magnetic field, however, the domains perpendicular to the load are decreasing. The compressive load effect is contrary [1, 2, 3, 4, 5].

The external magnetization parallel with tensile stress leads to increase of domains parallel with magnetization orientation. The parallel orientation results in more intensive movements of Bloch walls. The compressive stress causes rotation of walls into the direction of the exciting field and eliminates movements of Bloch walls.

As it was mentioned, Bloch walls move under the load of external magnetic field. This movement is not continuous but dynamic in the form of Barkhausen jumps with its characteristic vibration (Fig. 3). This movement can be indicated by a small coil as an electric pulse. The movement of Bloch walls is not continuous. Bloch walls rotate under the external load to the orientation of magnetic flow. The compressive stresses decrease intensity of Barkhausen noise and the tensile stresses increase this movement (Fig. 2). Barkhausen noise is usually evaluated through the envelope curves derived from the characteristic noise signal. The signal is processed through a conventional mathematic apparatus. Such parameters as the area of the envelope curve (correlates with the stress state) and amplitude of this envelope (correlates with the hardness of the surface layers, Fig. 1) are evaluated [6, 7, 8, 9].

The identification of Barkhausen noise is usually performed in the area of hysteresis loop Hc (Fig. 3). The device is based on the sensor with an integrated exciting and detecting part. The both systems are integrated to sensor with the contact area 16 mm^2. The penetration depth depends on the frequency of magnetic exciting field.

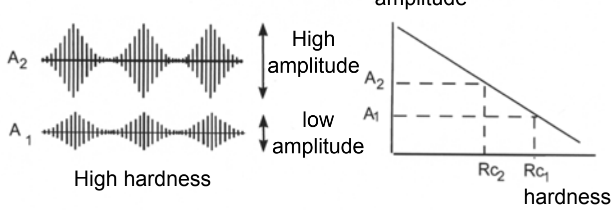


Fig. 1 Influence of hardness on character of Barkhausen noise [1, 2, 8, 10]
Obr. 1 Vplyv tvrdosti na charakter Barkhausenovho šumu [1, 2, 8, 10]

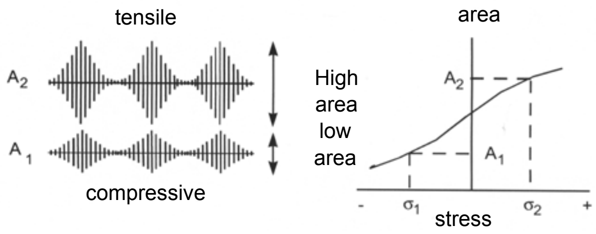


Fig. 2 Influence of stress on character of Barkhausen noise [1, 2, 8, 10]
Obr. 2 Vplyv napätia na charakter Barkhausenovho šumu [1, 2, 8, 10]

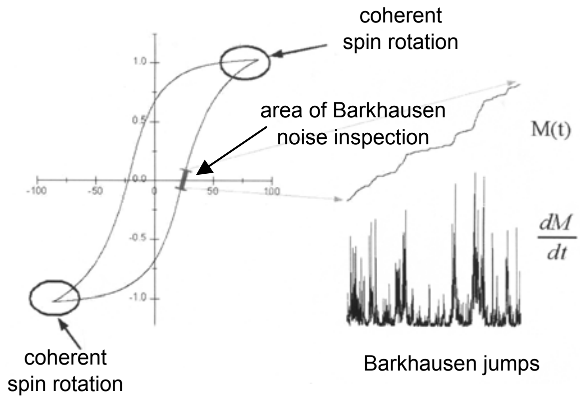


Fig. 3 Hysteresis loop of ferromagnetic material with the area of Barkhausen noise inspection [1, 2, 7, 8, 10]
Obr. 3 Hysterézna slučka feromagnetického materiálu s oblasťou merania Barkhausenovho šumu [1, 2, 7, 8, 10]

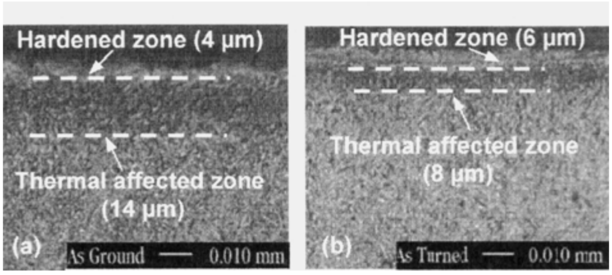
The main advantages of Barkhausen noise method is a very fast surface response (in seconds or minutes). Investigation can be carried out around the part to evaluate stress or structure distribution. This method can be utilized for design of automated cycles and robotic cells. The main disadvantage is associated with difficult calibration, complicated relationship between stress, structure and hardness. Moreover this method can be applied only for ferromagnetic materials.

Nowadays this method is applied to the monitoring of the most loaded surfaces in connection to a thermal load during grinding. A strong thermal effect increases the thickness of a thermally affected zone under the surface during grinding. At the same time, high tensile stresses are formed on the surface. Moreover, the thickness of hardened layer on the surface is very low. All these aspects cause an increasing of amplitude and the area of Barkhausen noise envelope curves.

Hard turning process is applied to finishing processes of parts in complicated shapes. Stress state, surface hardness and structure during hard turning completely differ from grinding process. Hard turning operations cause the formation of compressive stress in deeper layers under the surface [11]. In the case of grinding, the compressive stresses are usually only on the near surface. Tool wear shifts these stresses to a tensile area [12]. Mechanism of surface formation during hard turning is more complicated, this mechanism involves a very intensive plastic deformation, high temperatures, and high cooling rate. These aspects lead to the structure transformations of surfaces. Usually ′sandwich′ structure is formed as a combination of a white layer on the surface and a dark layer in the deeper layers [13]. This character of surface can be observed on the surface when the white layer is not formed (Fig. 4). Fig. 4 illustrates that in the case of ground surfaces the thickness of hardened layer (associated with the mechanical load) is lower, and the thickness of the dark layer (associated with the thermal load) is higher that that for turning process. On the other hand, the exact comparison of stresses, hardness and structure under the surface is complicated because of the variety of applied conditions for both operations (the influence of many additional factors).

The formation of the white layers is connected with the tensile stresses. The character of white layers, hardness, stress state and chemical composition is different for grinding and turning [12]. The risk of a thermal damage during grinding is high but white layers are not usually formed [10]. On the other hand, the intensive thermoplastic deformation during turning causes the formation of white layers in a very short time in connection with the tool wear. An increasing tool wear increases the thickness of white layers [14]. This difference has to be associated with the different condition in the tool – workpiece contact and the time of surface exposure (thermal and mechanical load). While grinding operations can cause the intensive diffusion processes, chemical composition of white layers after hard turning does not differ from the chemical composition of the deeper layers [12]

Because of the differences in the structure, stress and hardness state of surface it is assumed that the associated Barkhausen noise signals for both operations will be different. This paper deals with monitoring of surface integrity through the Barkhausen noise after turning and grinding in relation to tool wear.



a) finishing grinding b) hard turning
a) dokončovacie brúsenie b) tvrdé sústruženie
Fig. 4 „Sandwich“ structure after grinding and turning [13]
Obr. 4 „Sendvičová“ štruktúra po brúsení a tvrdom sústružení [13]

2 Conditions of experiments

The experimental study was carried out on roll bearing steel 100Cr6 (hardened - 62 HRC, and annealed – 27 HRC), 56 mm in external diameter, 40 mm in internal diameter, 125 and 10 mm in length.

Tab. 1 Experimental conditions during hard turning
Tab. 1 Experimentálne podmienky pre sústruženie

Cutting tool:	TiC reinforced Al_2O_3 ceramic inserts DNGA150408 (TiN coating), rake angle γ_n= -7º
Cutting condition:	v_c = 100 m.min^{-1}, f = 0,09 mm, a_p = 0,25 mm, dry cutting
Machine tool:	CNC Lathe Hurco TM8

Tab. 2 Experimental conditions during grinding
Tab. 2 Experimentálne podmienky pre brúsenie

Grinding wheel:	A 98 80 K9V 300x30x125 mm
Cutting condition:	v_c = 100 m.min^{-1}, v_f = 6,7 m.min^{-1}, v_w = 0,44 m.min^{-1} a_p = 0,025 mm (10 passes with 3 spark out passes), Ecocool MK3 (3% concentration), Single crystal diamond dresser
Machine tool:	2BuD

Tool wear during turning were measured under the microscope BK5. The analysis of stress state was carried out on 24 rings (3 rings per each 8 series) in 8 points on the periphery of the rings. The area of the envelope curve of Barkhausen noise MBN (related to stress state of surface) and the maximum amplitude of the noise MBN max (related to the hardness of the rings) were analyzed.

Parts 125 mm in length were applied to long term interaction (wear). Rings 10 mm in width were applied to the analysis of stress and structure, Fig. 5. The rings were investigated after certain intervals represented by a certain volume of removed material (Tab. 3). Turning operations were carried as a 1 pass of tool (cutting depth 0,25 mm). Grinding operations were carried out as 10 passes of cutting depth 0,025 mm with the consecutive spark – out passes.

Tab. 3 Intervals of measurements of rings and related removed material
Tab. 3 Interval merania krúžkov a s tým súvisiaci objem odobratého materiálu

n.	1	2	3	4	5	6	7	8
Removed material V (cm^3)	0	6,2	19	37	56	87	105	130

Except for Barkhausen noise method, the reference study through the mechanical method was also carried out. At first, non destructive tests were carried out on the surface with the following destructive test of stresses and structure.

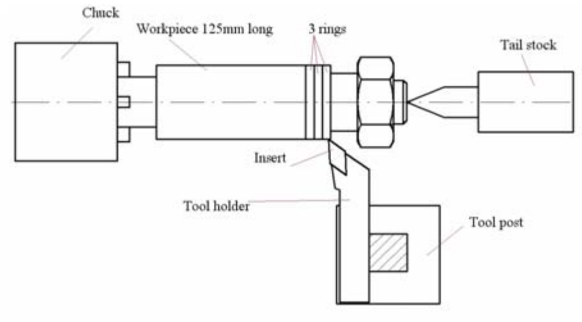


Fig. 5 Illustration of experimental setup
Obr. 5 Schéma experimentálneho merania

3 Analysis of surface integrity after grinding

Non destructive testing of surface through Barkhausen noise enables the evaluation of such aspects as stress, hardness or microstructure. These parameters are connected with the following factors:

- thermal load of surface,
- mechanical load of surface,
- mechanically and thermally induced structure transformations of surfaces.

A mechanical load during grinding is usually low (low cutting depths). The determining factor considering the surface integrity after grinding is the thermal load of surface. Thermal load in grinding is usually influenced by cutting conditions, machined material, grinding wheel and its wear.

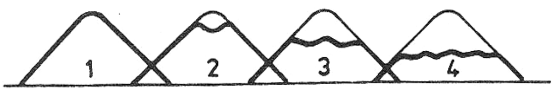


Fig. 6 Stages of grinding grain wear [16]
Obr. 6 Štádia opotrebenia brúsneho zrna [16]

A progressive change of grinding grains geometry, as illustrated in Fig. 6, is usually a dominant mechanism of grinding wheel wear. This process represents a stable period of grinding process. There is only a gentle rise in cutting temperature, dimensions of parts [17]. The stage 4 (Fig. 6) is the final one, geometry of grains does not change more and a grinding wheel should be redressed to remove the worn grains and activate a new layer. If a dressing of the grinding wheel is not performed, the instability of grinding process increases significantly; temperature in the tool – workpiece contact also increases [17]. All these factors influence the integrity of surface and significant changes in stress state and structure could be expected.

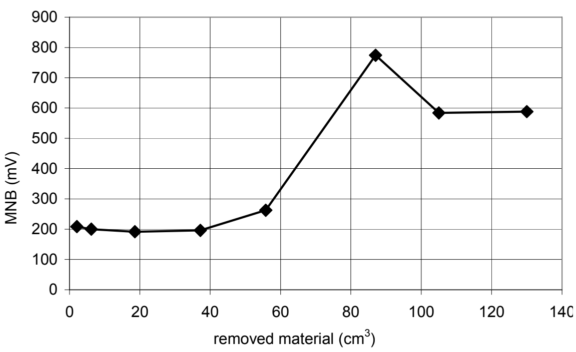


Fig. 7 Influence of grinding wheel wear on area of Barkhausen noise during grinding
Obr. 7 Vplyv opotrebenia brúsneho kotúča na plochu obálky Barkhausenovho šumu po brúsení

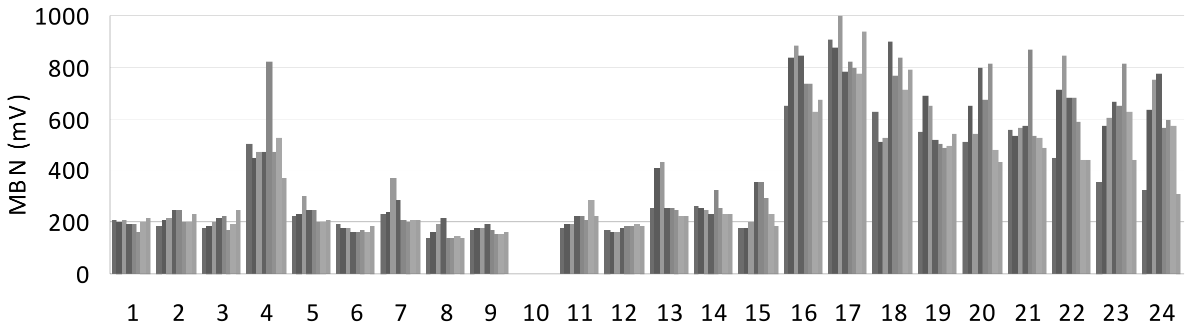


Fig. 8 Influence of grinding wheel wear on area of Barkhausen noise during grinding, a detailed view associated with the previous figure
Obr. 8 Vplyv opotrebenia brúsneho kotúča na plochu obálky Barkhausenovho šumu po brúsení, detail súvisiaci s predchádzajúcim obrázkom

Fig. 7 and 8 illustrate thermal load and associated state of residuals stresses derived from the envelope curve of Barkhausen noise *MBN*. The course of *MBN* in Fig. 7 corresponds with the progressive character of grinding grain wear (values in Fig. 7 represents average value derived from 24 measurements, 8 values around the 3 rings). A detailed view is illustrated in Fig. 8. The stable interval of grinding process reflects the stable *MBN* values with the following steep increase in MBN values (increasing intensity of friction processes in this interval and therefore higher temperatures in the tool – workpiece contact). The thickness of the heat affected zone changes in the same way as Fig. 9 shows. The photos of the heat affected surfaces, Fig. 9 and Fig. 10 show that the thickness of the heat affected zone does not change significantly at a certain interval of the volume of the removed material (V = 60 cm^3) with the following steep increase above this value.

Moreover, the distribution of residual stresses around the same part (values of *MBN*) significantly changes with an increasing volume of the removed material. Non homogeneity of stress distribution increases, Fig. 11 and Fig. 12. The values in this figure represent the maximum difference between the highest and lowest values of *MBN* around the same part. Fig. 11 illustrates that this non homogeneity after dressing is only 70 mV, about 450 mV was measured in the final stage of grinding process. The progressive change in grinding grain geometry does not affect only thermal load of surface but also the distribution of stress state. This non homogeneity is associated with the increasing instability of cutting process, oscillation of position between tool and workpiece. This oscillation changes the cutting depth and therefore temperature in the contact. The similar character of non homogeneity can be observed with respect to thickness of heat affected zone as Fig. 13 illustrates. The area of constant thickness of heat affected zone (Fig. 13a) in a certain position could be observed together with its variation in other position, Fig. 13b.

White layers do not form up to V= 60 cm^3. On the other hand, the steep increase of heat affected zone correlates with (together with *MBN* values) the formation of white layers on the surface. Their thickness is about 8 μm (Fig. 9 and 10a). This white layer is not continuous, its thickness varies, and some areas are without white layers (in scope of the same part). The areas without white layers correspond with the lower thickness of heat affected zone (Fig. 13b).

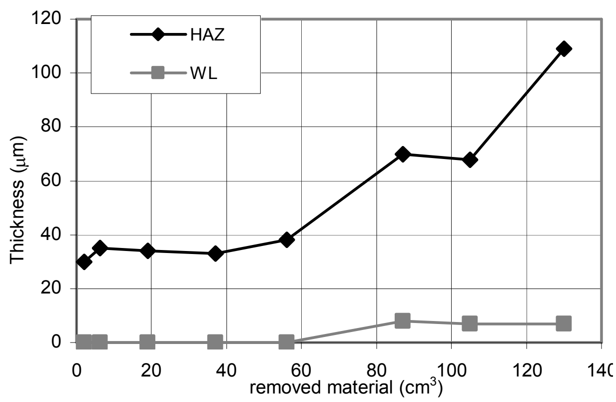
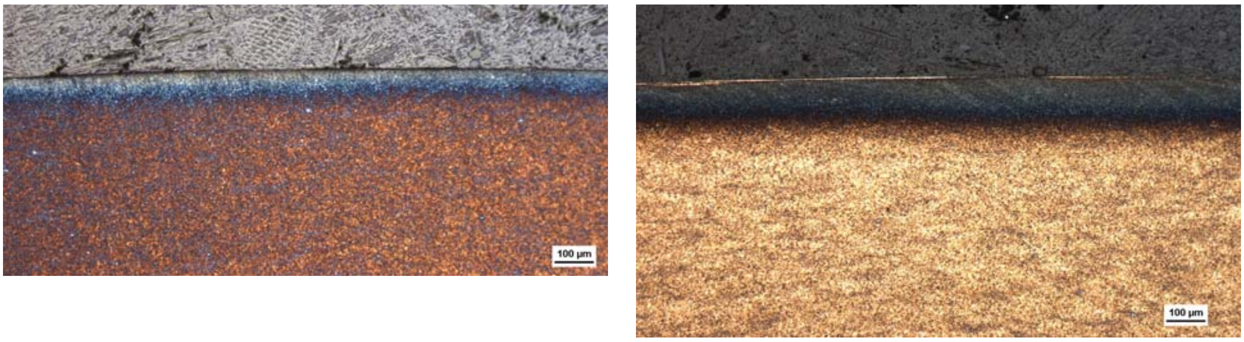


Fig. 9 Influence of grinding wheel wear on thickness of heat affected zone and white layers during grinding, HAZ – heat affected zone, WL – white layers
Obr. 9 Vplyv opotrebenia brúsneho kotúča na hrúbku bielej vrstvy a tepelne ovplyvnenej zóny po brúsení, HAZ – tepelne ovplyvnená zóna, WL – biele vrstvy



a) ring n.1, V = 3,1 cm^3 b) ring n.21, V = 105 cm^3

Fig. 10 Microstructure of surface after grinding
Obr. 10 Mikroštruktúra povrchu po brúsení

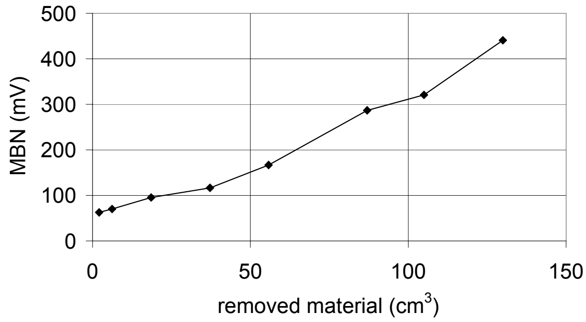
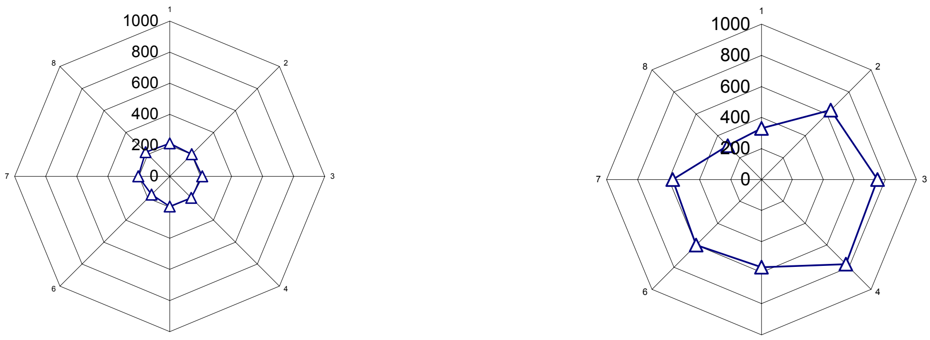
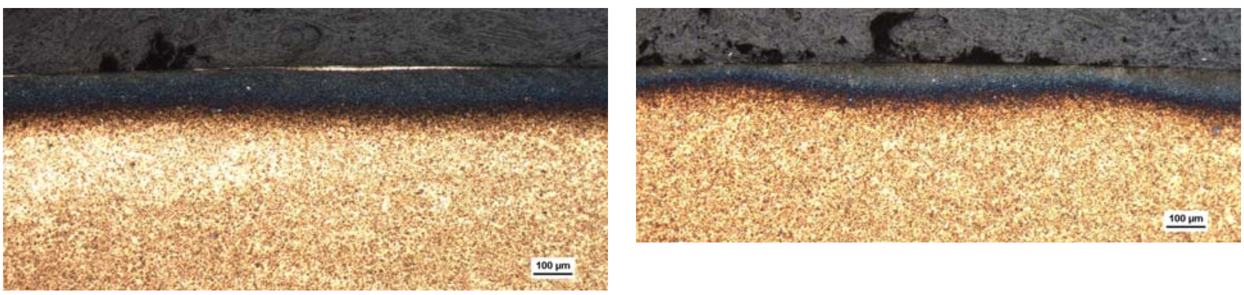


Fig. 11 Variance of stress distribution around the ground parts
Obr. 11 Variabilita rozloženia napätí po obvode brúseného krúžku



a) ring number 1 b) ring number 24

Fig. 12 Distribution of stress around the periphery of ground part
Obr. 12 Variabilita rozloženia napätí po obvode brúseného krúžku



a) ring n.24, V = 130 cm^3 - position 4 b) ring n.24, V = 130 cm^3 - position 8

Fig. 13 Microstructure of surface after grinding
Obr. 13 Mikroštruktúra povrchu po brúsení

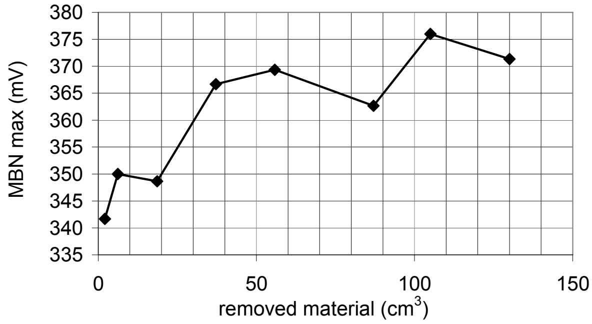


Fig. 14 Influence of grinding wheel wear on amplitude of Barkhausen noise after grinding
Obr. 14 Vplyv opotrebenia brúsneho kotúča na amplitúdu Barkhausenovho šumu po brúsení

The gentle decrease in surface hardness is associated with the progressive increase in temperature in the cutting zone. This phenomenon can be evaluated through Barkhausen noise amplitude rise *MBNmax*, Fig. 14.

4 Analysis of surface integrity after turning

Turning process leads to a different character of structure, hardness and stresses distribution. Material removal process is performed as a one pass of cutting tool. Because of high removal rates at the negative geometry of cutting inserts, the thrust force is very high. The determining factors considering surface integrity are processes in tool – workpiece contact. Machined surface is exposed to a very high mechanical and thermal load. This load increases with increasing tool wear *VB*. Some experimental and analytic studies show that temperatures in this contact usually overcome 1100ºC [18, 19]. The intensive mechanical load in the cutting zone is associated with the high thickness of material that underflows the cutting edge.

The relation between the thrust force and wear value *VB* determines the final state of surface integrity. This relation illustrates Fig. 15. The initial stage of cutting process causes the gentle decrease in the thrust force. This decrease is associated with the significant changes in cutting tool geometry (formation of a crater on tool rake as shown in Fig. 16 and 19). The crater on the tool rake becomes stable in the subsequent stages. Then the thrust force increases in connection with increasing tool wear *VB* at the tool back. In connection with an increase of the *VB* area of the tool – workpiece contact, the time of thermal and mechanical load of the surface is increasing. The normal phase of cutting process is associated with the stable interval with the low intensity of tool wear *VB*. Above the certain limiting values (in connection with increasing mechanical load) character of tool wear changes. The normal phase represents the microscopic breakage of a cutting edge. The final stages represent the massive breakage of macroscopic volumes of tool material. Shape, geometry and dimension of tool significantly change in the final stages of cutting process (Fig. 16c). This macroscopic character of tool wear leads to removal of a certain area of *VB*. Therefore the significant decrease in the thrust force can be observed at the end of the cutting process (Fig. 15). Thermal and mechanical load significantly change in connection with these processes.

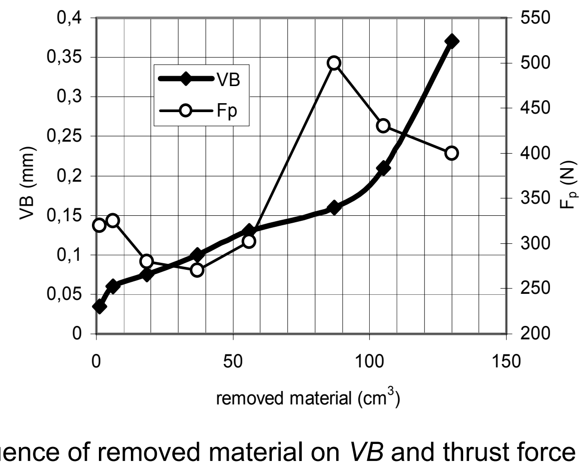
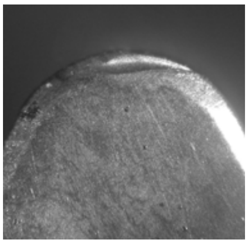
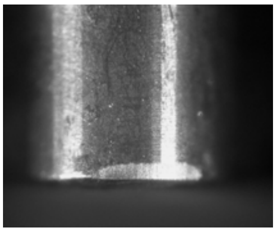
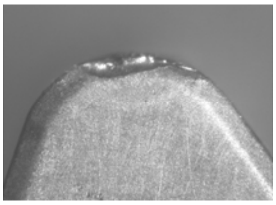


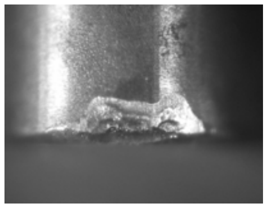
Fig. 15 Influence of removed material on *VB* and thrust force F_p for tuning
Obr. 15 Vplyv objemu odobratého materiálu na *VB* a F_p pri sústružení



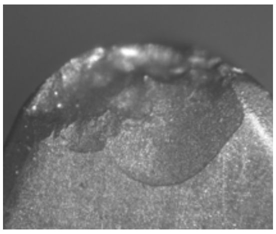


a) tool face, V = 56 cm^3 flank wear VB = 0,13 mm





b) tool face, V = 105 cm^3 flank wear VB = 0,21 mm



c) tool face, V = 130 cm^3 flank wear VB = 0,37 mm

Fig. 16 Photos of tool wear, real dimension of the figures 1,5 x 2 mm
Obr. 16 Fotografie opotrebenia nástroja, skutočný rozmer 1,5 x 2 mm

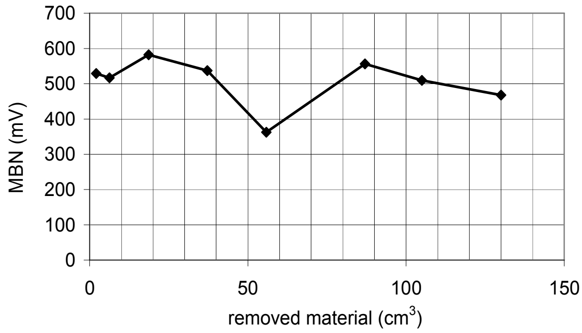


Fig. 17 Influence of tool wear on area of Barkhausen noise after turning
Obr. 17 Vplyv opotrebenia nástroja na plochu Barkhausenovho šumu po sústružení

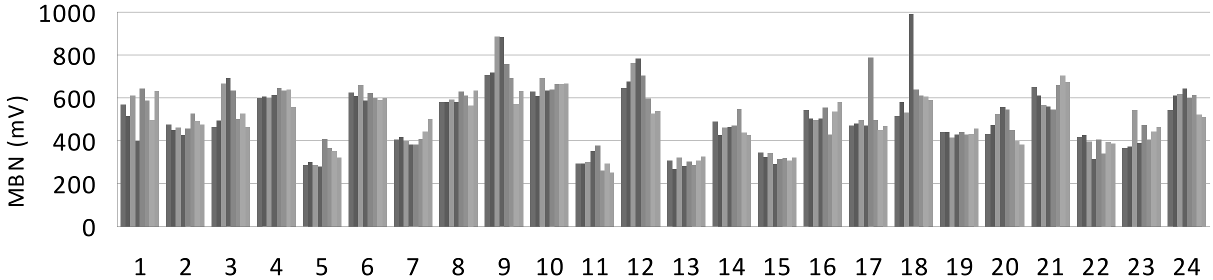
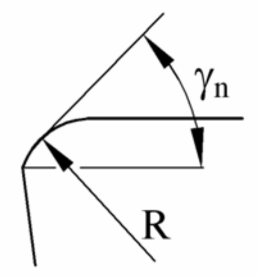
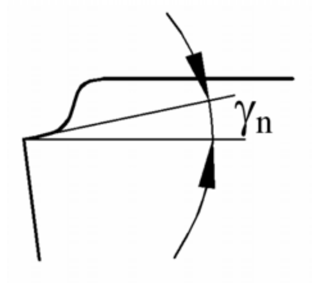


Fig. 18 Influence of tool wear on area of Barkhausen noise after turning,
a detailed view associated with the previous figure
Obr. 18 Vplyv opotrebenia nástroja na plochu obálky Barkhausenovho šumu po sústružení,
detail súvisiaci s predchádzajúcim obrázkom





a) before the turning test b) crater on the tool face
a) ostrý nástroj b) kráter na čele nástroja
Fig. 19 Illustration of tool geometry
Obr. 19 Obrázok geometrie nástroja

The variation of thermal and mechanical load during turning is more complicated than that for grinding process. In association with these changes, derived *MBN* values of Barkhausen noise are not monotone as illustrates Fig. 17. The local minimum can be viewed in the area V = 60 cm^3. From this point of view grinding processes are more suitable for monitoring through Barkhausen noise than those after turning processes. Grinding process leads to increase in thickness of heat affected zone. The influence of white layer formation is low because these layers are much thinner than thickness of heat affected zone. Moreover, hardness of surface after grinding is decreasing (increasing values of *MBN* max). Both aspects affect Barkhausen noise signals in the same way (increasing area and amplitude).

The relation between the tool wear, mechanical and thermal load of surface and surface integrity (derived from Barkhausen noise parameters – *MBN*) is more complicated. The process of tool wear shift the residual stresses to the tensile area, but hardness of surface is increasing because of formation of white layers on the surface (hardness of the white layer is higher than the deeper layers under the surface – about 1000 HV while in deeper layers only 760 HV [12]). Increasing hardness of surface layers can be assumed from decreasing values of MBN max in Fig. 22. The white layers is continuous and ration between thickness of white layers and heat affected zone is from 20 to 55% (in grinding operation only from 6,5 to 10%). The thickness of the heat affected zone is low (up to 12 μm, Fig. 20 and Fig. 21). Increasing hardness of surface layers eliminates the activity of Bloch walls and so decreases the amplitude and area of envelope curves of Barkhausen noise. On the contrary, tensile stresses increase the amplitude and area of envelope curves of Barkhausen noise. The analyzed parameters of Barkhausen noise envelope curves (area and amplitude) do not change in a monotone way and so it is difficult to apply these parameters for process monitoring. The structure of surface, texture of the surface and the next aspects take a significant role. Moreover, the different process of heat treatment and related different structure and hardness significantly affects the magnetoelastic response of surface. Increasing hardness of a structure causes the decreasing amplitude of envelope curves of Barkhausen noise despite of the increasing tensile stress of a structure. Therefore, it is necessary to modify experimental and analytical approaches and analyze other parameters of Barkhausen noise envelope curves.

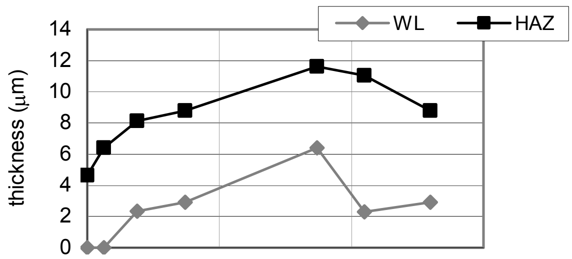
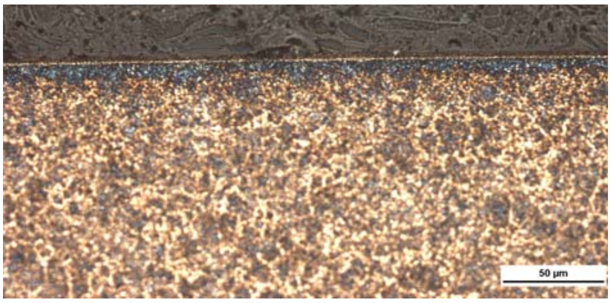
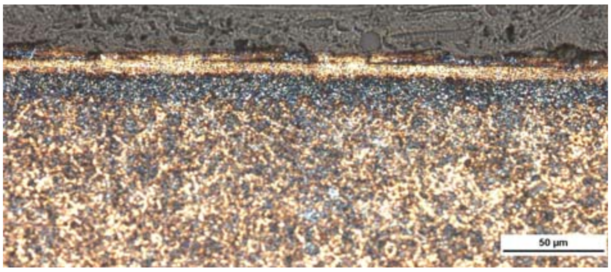


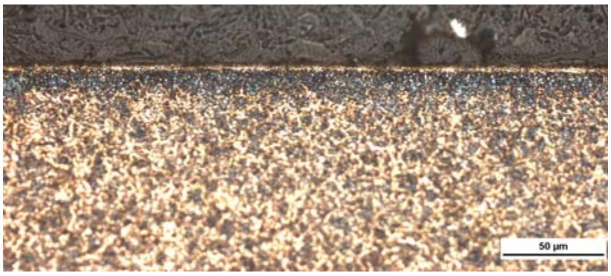
Fig. 20 Influence of tool wear on thickness of heat affected zone and white layers during turning
Obr. 20 Vplyv opotrebenia nástroja na hrúbku bielej vrstvy a tepelne ovplyvnenej oblasti po sústružení



a) ring n.11, V = 37 cm^3



b) ring n.16, V = 87 cm^3



c) ring n.24, V = 130 cm^3

Fig. 21 Microstructure of machined material after turning
Obr. 21 Mikroštruktúra obrobeného povrchu po sústružení

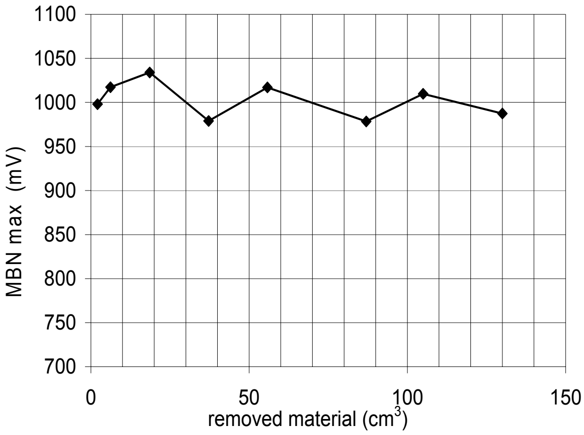


Fig. 22 Influence of tool wear on amplitude of Barkhausen noise after turning
Obr. 22 Vplyv opotrebenia nástroja na amplitúdu Barkhausenovho šumu po sústružení

The non homogeneity of stress distribution around the part is higher than that for grinding process in the first phases of test (Fig. 23 and Fig. 24). Its highest value corresponds with the stage of the high thrust force (V = 87 cm^3). The non homogeneity of stress distribution strongly correlates with the thrust force. This force causes the instability of a cutting process and the variation of a cutting depth thus the variation of mechanical and thermal load of surface.

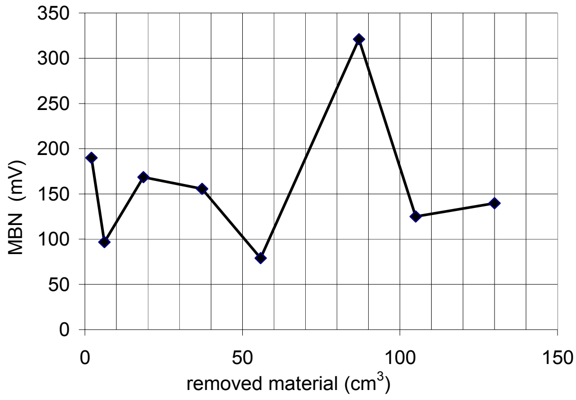
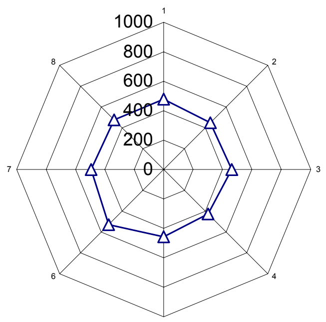
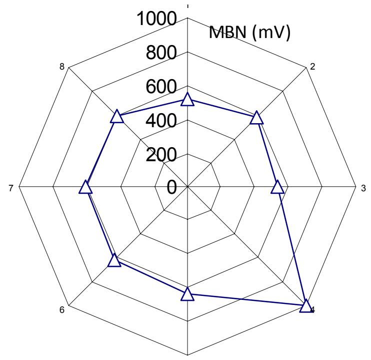


Fig. 23 Variance of stress distribution around the turned parts
Obr. 23 Variabilita rozloženia napätí po obvode sústružených krúžkov





a) ring number 2, V = 3,1 cm^3 b) ring number 18, V = 87 cm^3

Fig. 24 Distribution of stresses around the periphery of turned part
Obr. 24 Rozloženie napätí po obvode krúžkov po sústružení

5 Destructive testing of residual stresses

The non destructive analyses of residual stresses enable evaluation of stress distribution around the same part and measurements in the specific locations. This method does not enable evaluation of stresses in the different layers under the surface. *MNB* value is derived from the cumulative influence of magnetoelastic response all affected layers (penetration depth is about 0,1 mm in this case). Because of these aspects destructive mechanical method was applied to investigation of stresses in the different layers. The results of measurements are in Fig. 25 and 26.

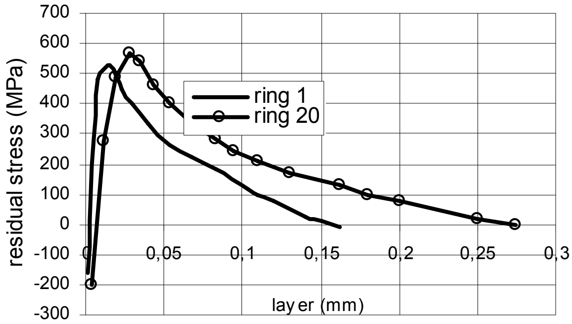


Fig. 25 Residual stresses after grinding
Obr. 25 Zvyškové napätia po brúsení

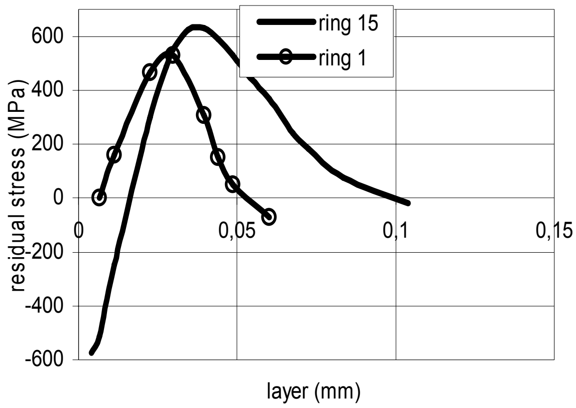


Fig. 26 Residual stresses after turning
Obr. 26 Zvyškové napätia po sústružení

The stress distribution in the different layers under the surface corresponds with knowledge about surface structure („sandwich" structure, Fig. 4) [8]. Moreover, these measurements correspond with the thickness of heat affected zone illustrated by Fig. 9 and 20. Fig. 25 shows stresses in the different layers under the surface after grinding. There is a very thin layer of compressive stresses on the surface increasing with the grinding wheel wear. The thickness of this layer after dressing is about 3 μm (ring n.1), and after V = 87 cm^3 this thickness is about 8 μm. On the other hand, thickness of the heat affected zone with the dominant thermal effect is significantly increasing with grinding wheel wear. Thickness of heat affected zone after dressing is 0,14 mm and 0,26 mm at the final stages of grinding. The maximum of tensile stresses does not change significantly.

The thickness of heat affected zone after turning is lower than that for grinding process. The initial stages of turning process form tensile stresses under the surface as illustrated in Fig. 26. The thickness of the heat affected zone is 0,05 mm and the maximum of tensile stresses is 530 MPa. An increase in tool wear leads to formation of compressive stresses in the near surface with the maximum about -600 MPa. The thickness of compressive stresses is 16 μm. Thickness of heat affected zone is increasing and reaches 0,092 mm. The maximum of tensile stresses is 630 MPa.

The difference in stresses distribution between grinding and turning process is affected by the intensity of thermal and mechanical load together with the time exposure of the machined surface. The temperature in the cutting zone is much higher (1100ºC [9]) than that during grinding process (from 550 to 600ºC [20]). On the other hand the maximum of tensile residual stresses does not differ significantly. The significant factor, except for the thermal load, is the mechanical load. The thermal load shifts residual stresses to the tensile area while mechanical load to the compressive area. Value, direction and distribution of stress under the surface is given by a balance between these effects (structure transformation can also take a significant role).

6 Discussion and Conclusion

Another significant factor considering stress and structure under the surface is the time of the surface exposure (time of mechanical and thermal load). The thickness of heat affected zone after turning is only (for VB = 0,15 mm) 25 % of the heat affected zone after grinding. This difference is connected with the much longer period of a contact between a certain area of machined surface and tool during grinding than that for turning. The main movement during turning is carried out by workpiece and so the speed of surface movement is connected with the cutting speed (100 m.min^{-1}). The main movement during grinding is carried out by grinding wheel and so the speed of surface movement is connected with the feed speed (v_f = 6,7 m.min^{-1}). The contact length during grinding is approximately double of the theoretical length (in this case 0,04 mm). Contact length during turning corresponds with VB value. This value changes from 0 to 0,15 mm. Above this value the microscopic breakage of cutting edge transforms to macroscopic breakage. This mechanism leads to decrease in the real value of VB, Fig. 16. The decrease of VB has to be associated with the decrease in the thickness of white layers in this stage. The calculation of the surface time exposure (derived form contact length and surface speed) shows that this time is four times higher for grinding than that for turning (under the higher mentioned conditions). This ratio corresponds with the ratio between the thicknesses of heat affected zones.

The application of Barkhausen noise to monitoring of surface integrity after turning operation will require the follow - up research. The modification of the conventional approach (the evaluation of the amplitude and the area of envelope curve) will have to be carried out through the multi parametric evaluation.

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ANALÝZA NIEKTORÝCH ASPEKTOV INTEGRITY POVRCHU PO BRÚSENÍ A TVRDOM SÚSTRUŽENÍ

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🗝 Kľúčové slová: Barkhausenov šum, zvyškové napätia, brúsenie, sústruženie

Článok sa zaoberá využitím Barkhausenovho šumu na analýzu zvyškových napätí po brúsení a sústružení. Výsledky ukazujú na rozdiely v rozložení napätí po brúsení a sústružení. Pri sústružení je zmena tepelného a mechanického zaťaženia obrobeného povrchu v súvislosti s opotrebením nástroja zložitejšia v porovnaní s brúsením. S tým súvisí aj skutočnosť, že charakteristická zmena hodnôt *MBN* po sústružení nie monotónna, ale vykazuje lokálne minimum v oblasti 60 cm^3. Pri brúsení je zmena *MBN* hodnôt oveľa vhodnejšia čo sa týka praktického využitia Barkhausenovho šumu na monitorizáciu tepelného poškodenia povrchov. Súvisí to so skutočnosťou, že pri brúsení dochádza k rozširovaniu tepelne ovplyvnenej zóny. Vplyv vytvárania bielych vrstiev je menej výrazný, vzhľadom na to že sú oveľa tenšie v porovnaní s hrúbkou tepelne ovplyvnenej zóny a navyše nie sú kontinuálne, ale len miestne. Taktiež dochádza k poklesu tvrdosti na povrchu po brúsení čo dokumentuje nárast hodnoty *MBNmax*. Oba vyššie uvedené aspekty pôsobia vo vzťahu k hodnotám *MBN* rovnakým smerom, a teda zväčšujú hodnoty *MBN*. Pri sústružení je hrúbka tepelne ovplyvnenej zóny oveľa menšia. Biele vrstvy sa vytvárajú už v oblasti normálneho opotrebenia a spolu s hrúbkou tepelne ovplyvnenej zóny rastú tak ako sa zväčšuje oterová plôška na chrbte nástroja. Biela vrstva je súvislá a na rozdiel je pomer medzi jej hrúbkou a hrúbkou tepelne ovplyvnenej zóny oveľa vyšší ako pri brúsení. Nárast hrúbky bielych vrstiev ako aj nárast tvrdosti povrchových vrstiev dokumentuje aj mierny pokles hodnoty *MBNmax*. V súvislosti so skutočnosťou, že hrúbka tepelne ovplyvnenej zóny je výrazne menšia pri sústružení ako pri brúsení, že pomer medzi hrúbkou bielej vrstvy a hrúbkou tepelne ovplyvnenej zóny je vyšší, ako aj v súvislosti s narastajúcou tvrdosťou povrchových vrstiev je potom ťažšie identifikovať zmeny v povrchových vrstvách prostredníctvom Barkhausenovho šumu. Súvisí to so skutočnosťou, že zväčšovanie hrúbky tepelne ovplyvnenej zóny na jednej strane spôsobuje nárast hodnôt MBN, avšak na starne druhej rastúca tvrdosť pôsobí na hodnoty *MBN* práve v opačnom smere. Výsledné hodnoty *MBN* v súvislosti s opotrebením nástroja sú potom dané sumárnym účinkom oboch vplyvov.

ZPĚT