SUCCESSFUL OUTCOMES OF COLLABORATION BETWEEN A UNIVERSITY-BASED RESEARCH AND DEVELOPMENT FACILITY AND A MANUFACTURING FACTORY

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University facilities often have extensive technical equipment for complex high-accuracy engineering calculations. These facilities strive to verify their results in practice. Such an opportunity arose in collaboration between the Centre for Forming Machine Design Research (CFMDR, Centrum výzkumu konstrukce tvářecích strojů) and the company TS Plzen, which focused on a new design concept for a hydraulic press for open-die forging. This press was the CKV 120/140 type; built for and supplied to the company SUNAN.

KEYWORDS

hydraulic press, free forming, design, finite element method, optimization

1 INTRODUCTION

Since 1959, our department at the University of West Bohemia (UWB) has been active in engineering design of forming machines, predominantly in collaboration with the TS Skoda company, which now operates under the name TS Plzen.

After the Research Institute for Forming Machines (VUTS), based in the city of Brno, had been dissolved, this specialist sector was in need of a facility which could follow on from this Institute's successful activities.

Upon an agreement between managers of forming machine manufacturers, with the support of the Association of Engineering Technology – SST and the Research Centre at the Czech Technical University in Prague, the Centre for Forming Machine Design Research (CFMDR) was established by the Rector's decision at the UWB in 2008, bringing together professionals with long-standing experience in designing forming machines, with the support from leading experts from industry hired on the basis of special contracts.

The projects carried out by the CFMDR included contracts on behalf of manufacturers of forming machines, as well as initiatives launched by science-funding agencies.

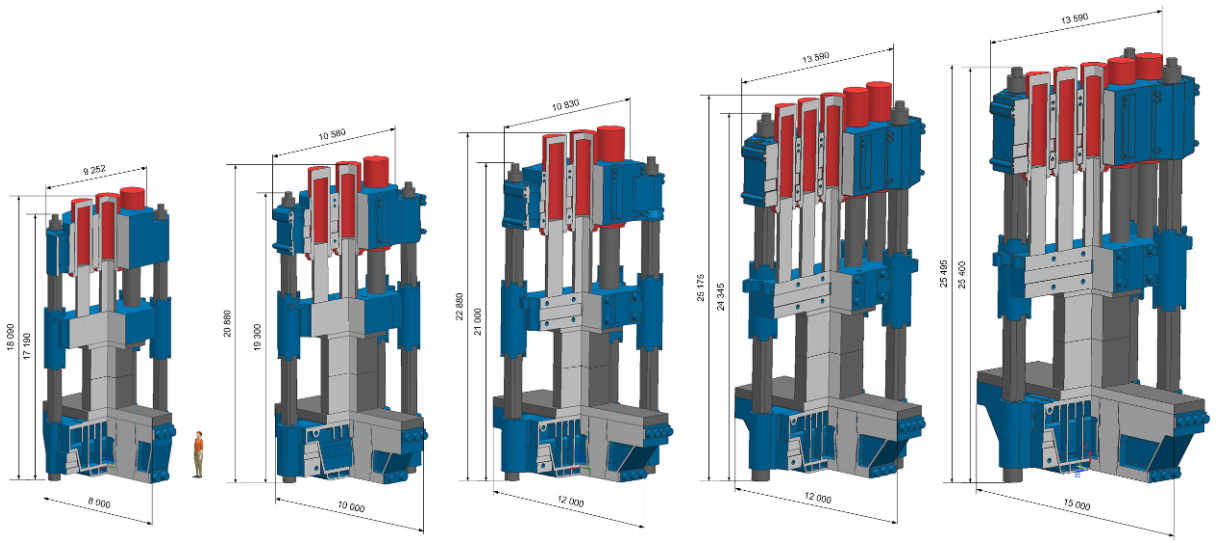
Much of the collaboration with manufacturing companies involved Smeral Brno and TS Plzen, the largest manufacturers of forming machines in the Czech Republic.

Based on this collaboration, grants were awarded in 2009 to the CFMDR by the Ministry of Industry and Trade to support research into forming machines.

2 OUTCOMES OF JOINT PROJECT WITH TS PLZEŇ

A joint project with TS Plzen involved developing design solutions for the CKV series of large forging hydraulic presses with forces in the range from 100/120 to 200/240 MN.

We have completed the project successfully. With the aid of public funding (from the Ministry of Industry and Trade of the Czech Republic), we have laid foundation for developing advanced design solutions for CKV-series presses in the future. As a result, TS Plzen has become a very competitive player in this sector.



CKV 100/120 1 760 t | CKV 120/145 2 500 t | CKV 140/170 3 150 t | CKV 170/200 4 050 t | CKV 200/240 4 700 t

Figure 1. Newly-developed CKV-series of hydraulic presses

In these public-funded projects, several academics and students at the University of West Bohemia have gained invaluable hands-on experience.

3 SPECIFIC MACHINE DESIGN SOLUTION

Outcomes of one particular public-funded project soon led to new foreign contracts for the TS Plzen company. In a stiff foreign competition, TS Plzen has won a contract for designing a CKV press for the Chinese company SUNAN.

It was a hydraulic forging press with a force of 120/140 MN (CKV 120/140).

The design specifications submitted by SUNAN were particular. Although the formerly-developed series of presses were still usable as a design basis, the alterations resulting from the customer requirements interfered with the original optimized design solutions. Consequently, the specific designs and verification calculations for the design concept that had been developed at TS Plzen were to be reworked in collaboration with the CFMDR.

The design concept was examined at the CFMDR using FE simulations which involved all the necessary calculations. The results were used for design optimization that aimed at reducing the stresses in and the weights of individual components.

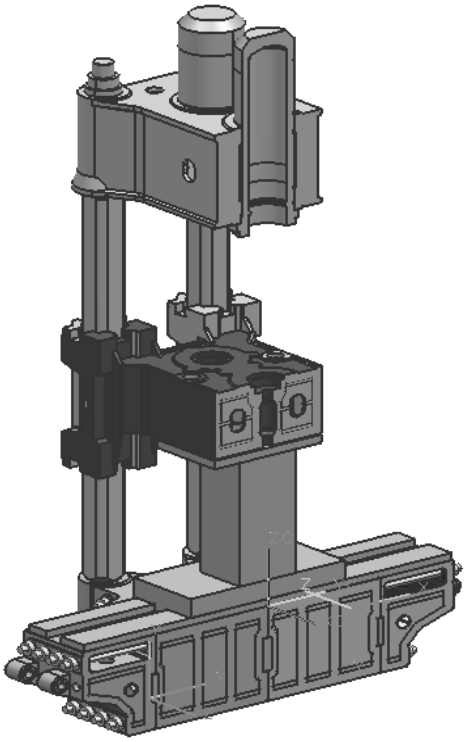


Figure 2. Model of one half of the CKV 120/140 SUNAN press

The optimization process consisted of no less than three stages. The outcomes were rather surprising: our optimization led to the savings of several tens of tonnes of material, maintaining all required characteristics, including sufficient stiffness.

The simulations showed stress distributions in and displacements of individual parts of the machine, from which frame distortion values could be calculated.

The frame model was investigated using the most adverse load which can occur during forging. This was an eccentric load, at the eccentricity magnitude requested by the customer. The load was acting on the press at the time when the dies were not touching: between the dies, there was a workpiece of a height that caused maximum tilt of the moving crosshead.

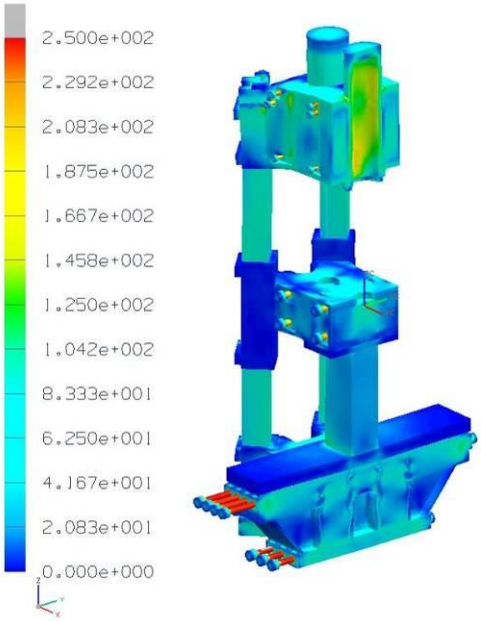


Figure 3. Stress distribution in the press frame after optimization (the model only comprised ½ of the frame)

As Figure 3 shows, all stress peaks were removed by the optimization and all stresses in the frame were below the allowed limit of 150 MPa, which also meant below the fatigue limit.

Even after the modification, some parts of the frame still contained underutilized material (blue regions), as shown in Fig. 3, because weight optimization in these regions was ruled out for design and operating reasons.

Pre-stressing anchors were made of a high-quality material with a yield strength of 600 MPa and their allowed loads were therefore much higher than those of the cast parts of the frame (Fig. 3, red-coloured anchors).

Main cylinders are also designed to higher allowed stresses than the cast parts of the frame – as seen in Fig. 3; it is approx. 180 MPa.

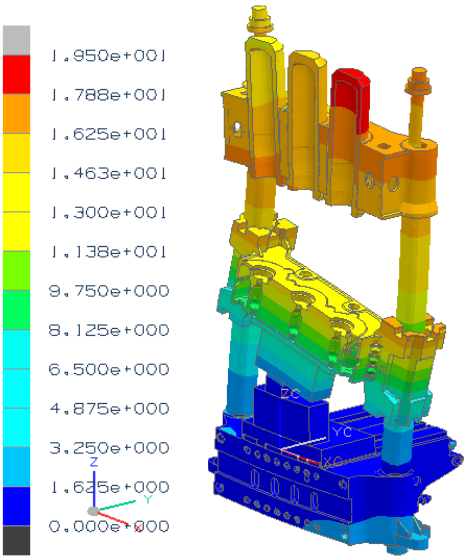


Figure 4. Frame displacement in the longitudinal direction

Figure 4 shows that the largest displacement caused by eccentric load, approx. 20 mm, is found at the top of one of the main cylinders.

As the height of the machine is around 26 metres, this magnitude of displacement is relatively small, indicating a good stiffness of the press.

After all calculations had been analyzed and the design optimized, a refined 3D model of the press was developed, the design solution was created and the final dimensions of all functional parts were specified, Fig. 5.

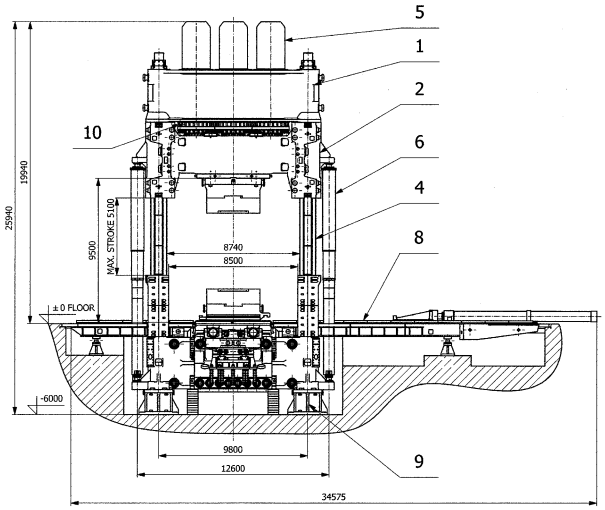


Figure 5. Design of the CKV 120/140 (SUNAN) press with the basic dimensions indicated (as viewed from the manipulator side)

These were the input data for the detailed elaboration of the design solution which was eventually finalized at the TS Plzen design department.

Components of the press were manufactured to technical documentation. The press was then built under the guidance of seasoned engineers and fitters of TS Plzen in collaboration with on-site personnel at SUNAN.

The scope of this work (the final mass of the press was 4095 tonnes) and the customer requirements for a unique solution placed extraordinary demands on mental resilience of the specialists involved: an error in the design could ultimately bankrupt the manufacturer, given the final price of approx. CZK 780 million (EUR 30 million) of the hydraulic press alone (the project also involved a manipulator and other accessories).

Figure 6. Scaffolding around the assembled CKV 120/140 SUNAN press prior to final assembly operations

Figure 7. Assembled CKV 120/140 press ready for testing

The trial operation finished successfully several years ago and the press has been in trouble-free service ever since.

4 TECHNICAL CHARACTERISTICS

FORCES OF PRESS

nominal forging force	120	MN
forging force – I grade	39.82	MN
forging force – II grade	79.64	MN
forging force – III grade	119.46	MN
nominal upsetting force	140	MN
upsetting force	139.37	MN

max. eccentricity - radius – at stage III forging force (120 MN) in the plane of the frame is 500 mm

WORKING PRESSURE OF MAIN CYLINDERS

forging pressure of main cylinders	30	MPa
upsetting pressure of main cylinders	35	MPa

MAIN CYLINDERS

No. of pressing cylinders	3	pcs
diameter of pressing cylinders	1300	mm

WORKING STROKE

working stroke (daylight between swages)	5000	mm
max. stroke (distance between moving crossbeam and column stopper)	5100	mm

BASIC DIMENSIONS

opening of the press (maximum daylight)	9800	mm
forging table to the top of upper die	9500	mm
daylight between columns in forging table axis	8500	mm
daylight between columns in cross shifting axis	2400	mm
distance between column axes	9800/3730	mm
height above the floor	19940	mm
press depth under the floor	6000	mm
length of the forging table	13408	mm
width of the forging table	5356	mm
total press weight	4095 t	

5 CONCLUSION

The CKV 120/140 SUNAN press is one of the largest machines of its kind – among hydraulic open-die forging presses.

Although our country is small in global comparison and its economy perhaps even smaller, we can be proud of our excellent engineers whose ideas and advanced engineering solutions succeeded in strong international competition against top specialists, and led to realization of a unique product.

This press is unsurpassed in terms of size, being both a prototype and a final product. Machines of this kind do not tolerate trial-and-error attempts. All their aspects must be well-thought-out and brought to perfection. Mistakes are unacceptable because not only all potential contracts would be lost due to perceived unreliability but the manufacturer could even go bankrupt. No manufacturer can afford this.

That is why virtual modelling and diagnostics of the press carried out by the CFMDR at the University of West Bohemia played was of major importance. All the results were verified and compared against real-world data. The purpose of this extensive effort was to compensate for the unavailability of a prototype and the impossibility to validate the design solution.

For this reason, unusually high demands were placed on the proficiency and competence of the specialists involved, concerning not only their expertise but also their mental strength – since errors were unacceptable. To complete the project, all the specialists involved, from both TS Plzen and the CFMDR at the University of West Bohemia, had to use all their skills and abilities. We can be proud of this success, meaning not just us involved but all citizens of the Czech Republic. Engineering feats of this kind worth billions are not achieved every day in our country. The key element behind this success is the good collaboration between TS Plzen and the Centre for Forming Machine Design Research at the University of West Bohemia.

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