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MULTIDIRECTIONAL FORGING AND IMPROVEMENT OF HYDRAULIC FORGING PRESS USING ADDITIONAL DEVICES

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Abstract: *This paper deals with possibility of multidirectional forming. During design process of new device for multidirectional forming it is necessary to consider optimal usage of material and resistance against loading during technological operation. Design of new equipment for multidirectional forging is here performed. It is designed starting from idea of using standard hydraulic free forging press with upper drive as additional device. Forming with increased accuracy is nowadays highly requested by all companies and producers have to improve design of forging machines. These better forged parts can be produced with lower cost as normal parts. It is caused by fewer machining operations. New design of multidirectional forming has better dynamic resistance. It is suitable for dynamic and shock loading. The solution is done by using finite element method in all simulations. Also all simulations are validated by comparing with real measurement during forging operation. The paper presents the basic design of multidirectional forging device and also the main parts that are checked in terms of strength and displacement. Also, the whole device had undergone dynamic analysis. This analysis shows suitability for high-speed forging with frequency up to 100 strokes per minute.*

Key words: *Multidirectional forging, simulation, measurement, hydraulic press, modal analysis, mechanical stress, multiway.*

1. INTRODUCTION

Multidirectional forming is a progressive and modern way how to produce forgings with complex shape. It is possible to make products which are not possible to make using other technologies. Using multidirectional forging produces less material waste material than conventional machining of forgings [1–3].

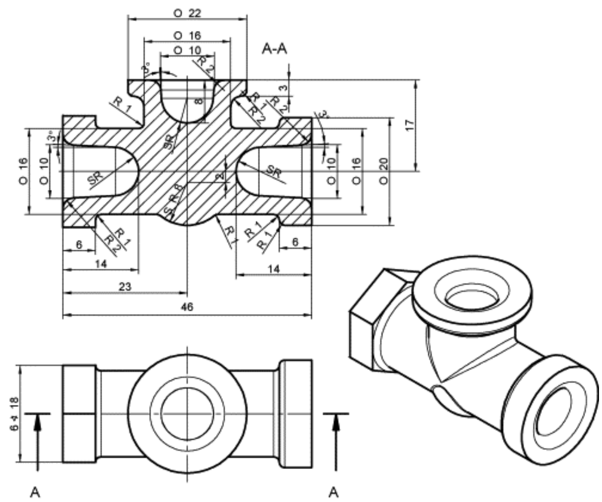

Fig. 1. Example of simple forging made by multidirectional method.

Fig. 2. Example of one-purposed multidirectional forging device with typical forged part –variant 1.

Figure 1 shows one of the classical products made by multidirectional forging. Generally are by this technology produced "T" shaped pipes, exhaust pipes and other forging with complex shape. These forged parts have higher strength than machined parts.

Today are for this technology most commonly used special machines with no other usage. Some of these one-purpose machines are on Figs. 2 and 3 [5, 13, and 16].

Nowadays, the machines for multidirectional forging (Multiway) are not so often used in forging factories.

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Fig. 3. Example of one-purposed multidirectional forging device – variant 2.

On market there are only single-purpose machines dedicated only for one type of forging.

The basic technological principle of this special forging technology is simple. During this technology there are 3 main movements (according to Fig. 4). First movement is closing of upper and lower die. Next is movement of main (vertical) ram and third is horizontal movement of side rams. The possibilities of movement sequences are presented in Fig. 4.

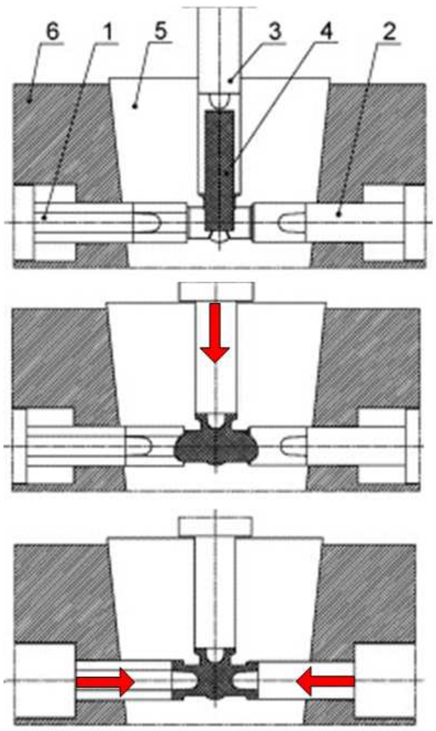

Fig. 4. Principle of multidirectional forging (1, 2 – horizontal punch; 3 – vertical punch; 4 – forged material; 5 – die; 6 – holder).

For companies it is very expensive to buy single purpose machine only for multidirectional forging. One of the possibilities is to design new additional device for classical free forging press. These presses are commonly used in all forging factories.

In our research centre for forming machines the first design studies were performed in cooperation with factories and hydraulic press producers. The design process is described further.

2. DESIGN OF ADDITIONAL DEVICE FOR MULTIDIRECTIONAL FORGING

It is possible to use hydraulic press for free forging as basic machine for multidirectional forging, because this press has sufficient large working space between movable and lower crossbeam and also generates enough forging force.

Hydraulic press has only vertical direction of forging force. Additional device has to produce horizontal force. The usage of this additional device extends usability of forging press.

This design started from classical free forging hydraulic press with four columns, three working cylinders and middle movable crossbeam.

The maximum force of this press is 200 MN. For this press an adaptive device was created, allowing the generation of forging force also in horizontal direction. The vertical movement of additional multidirectional device is allowed because it is connected to the press columns.

The assembling of hydraulic press and multidirectional forging device should not take more than 4 hours.

Additional device itself is already connected to the source of hydraulic fluid. In forging factory, the transport crane is used for handling heavy parts.

After finishing the multidirectional technology, this device can be this removed and the press can be used for normal operations like upsetting, widening or forging of rings.

The new forging device has the parameters shown in Table 1.

Table 1

Force parameters of multidirectional forging device

Vertical ram force	**Nominal force**	200/130	MN
	Main ram force	125	MN
	External piercing force	75	MN
	Total forge force	200	MN
	Main return force	25	MN
	Pierce return force	8	MN
Horizontal ram force (each side)	**Main ram forge**	130	MN
	Internal or external piercing force	50	MN
	Main ram return force	10	MN
	Piercing ram return force	6	MN
Eject ram force	**Eject force (Piercing force)**	20	MN
	Return force	5	MN

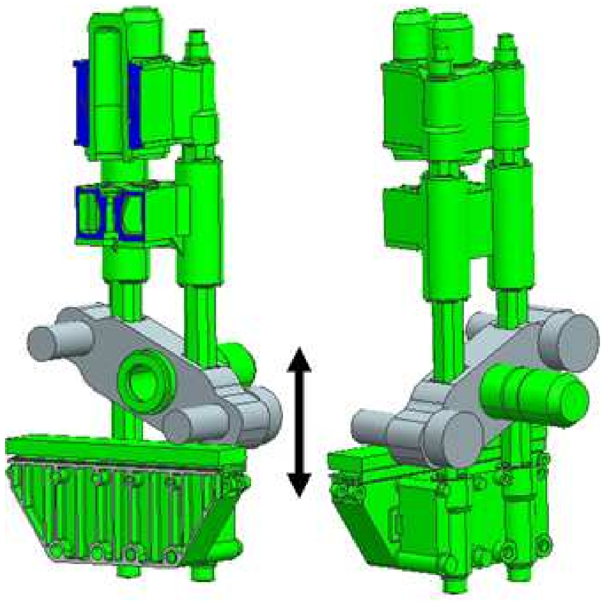

Fig. 5. Simulation CAD model (one half because of symmetry).

The multidirectional forging is applied by connecting two crossbeams to the hydraulic press columns. These two crossbeams are connected by two rods and have two working cylinders.

The principles are shown in Fig. 5.

A disadvantage of the proposed solution is the necessity of creating relatively long rods for connecting both additional crossbeams (coloured in grey) to each other. To ensure the possibility of access to the working space, the entire device is not horizontal. The angle to horizontal plane is 25 degrees (Fig. 6). This allows the mechanical manipulator to handle the forged parts and access the space of forming dies.

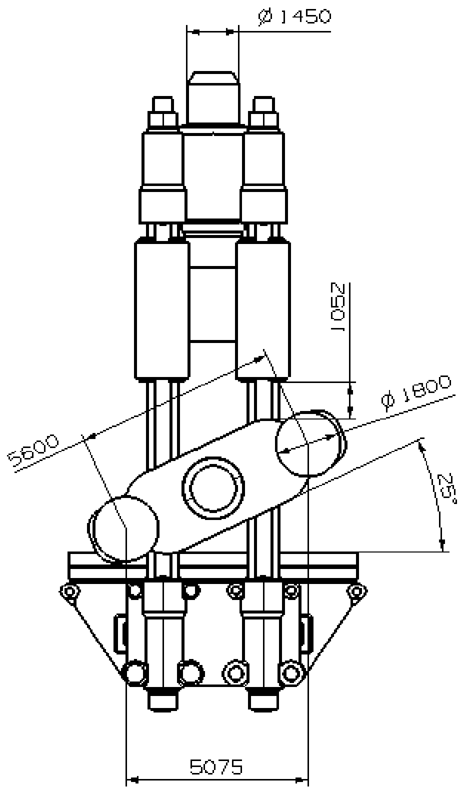

Fig. 6. Basic dimensions.

Another disadvantage is the reduction of the movable crossbeam stroke to approximately 1000 mm. It means that maximal height of forged piece can be 500 mm.

Diameters of working cylinders are:

- work cylinder vertical: 1000 mm;
- working cylinder side: 1160 mm.

2.1. Strength analysis

Because the force generated on main columns of hydraulic press was high (130 MN), it was necessary to check strength and maximal stress. According to virtual simulations done by finite elements method, the maximum displacement is of 4.6 mm (Fig. 7) and maximum Von-Misses stress is of 150 MPa (Fig. 8).

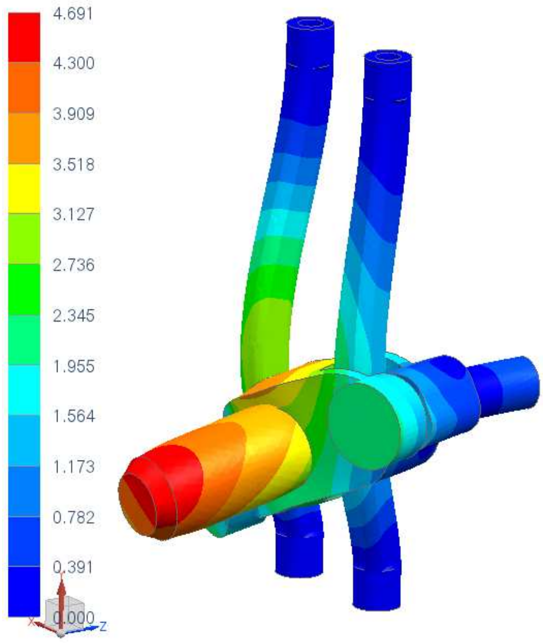

Fig. 7. Maximal displacement of columns and additional device.

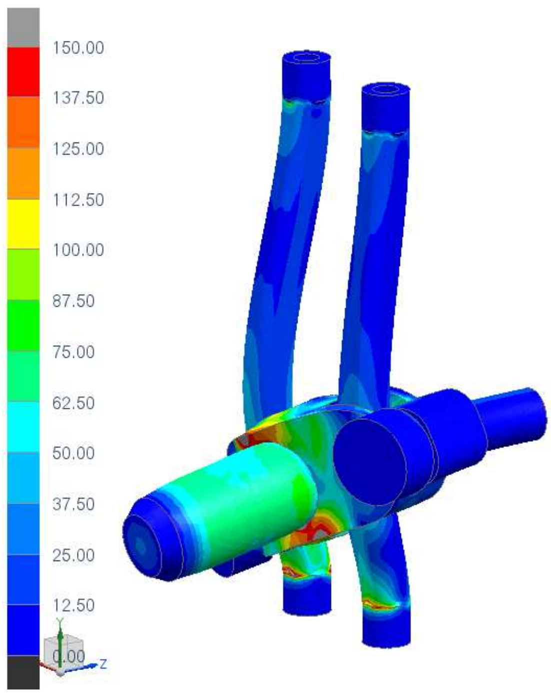

Fig. 8. Maximal Von-Mises stress of columns and additional device.

These values are allowable. For this simulation only columns and one half of additional device were used (shown in Fig. 7).

All analyzes were performed using NX Nastran CAD/CAE software. For creating meshes, the tetrahedral type of element with maximum element size up to 100 mm was used. Also, the adaptive meshing with higher mesh density closer to point of interest was used.

Between all parts contact boundary conditions with friction parameter 0.1 (steel to steel) were considered.

Because this device is symmetric (it has two planes of symmetry), for reduction of computational time, only one half (if possible) was used with appropriate boundary conditions [4, 6, 7, 8, and 9].

2.2. Dynamic properties and dynamic analysis

Some of the forging operations work with higher frequencies. Also multidirectional forging can be automated with higher rate of strokes. It is necessary to check dynamic properties of forging machine and minimize vibrations. Lower vibrations lead to more precisely forged parts.

The biggest problem of dynamic vibrations and twisting of hydraulic press is the contact of upper and lower die. This dies has to be in proper surface to surface contact. When vibrations occur, the contact is sometimes only edge to surface and the accuracy of forged parts is not suitable.

One of the possibilities of dynamical simulations is the modal analysis. This analysis shows natural frequencies of oscillations. These frequencies have to be as high as possible. Because less stiffness is obtained in forging machine without additional device, modal analysis is done without it [10, 11, and 12].

Figures 9 and 10 show the first two modal shapes for hydraulic press with pre-stressed four-column frame and upper drive with maximum force of 200 MN.

First modal shape (6.496 Hz) corresponds to moving of the press in the direction of the axis of the press table.

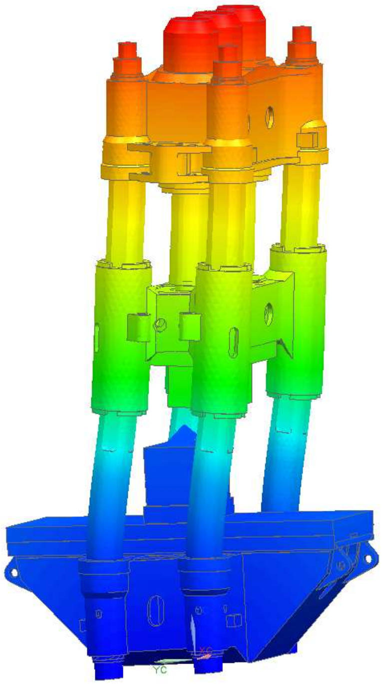

Fig. 9. First modal shape (6.496 Hz).

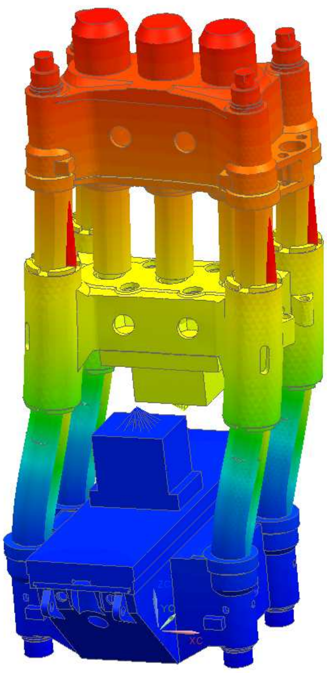

Fig. 10. Second modal shape (7.955 Hz).

Second modal shape (7.955 Hz) corresponds to the motion of the press in a direction perpendicular to the axis of the table.

These values can be converted to frequency of strokes. The lowest critical frequency is 390 strokes per minute. This value is much higher than real strokes rate of hydraulic press. From dynamic point of view this design is suitable.

3. VALIDATION OF RESULTS BY COMPARING CAE METHODS WITH REAL EXPERIMENT

It is necessary to validate the CAE model and all virtual simulations. The best way to do it is to compare virtual the model with the real hydraulic press.

For this task, it was chosen the easiest technological operation setting. In the CAE simulation, the time dependent solution with maximal time 10 seconds was performed. In the time interval 0–2 sec and 5–7 sec the maximum force of press was applied [14, 15]. This caused oscillations of the whole hydraulic press. These oscillations correspond to force impulses.

In Fig. 11, the whole virtual model of hydraulic press (without additional device) is shown together with the point used for displacement measuring.

The same boundary conditions were applied on real hydraulic press of type CKV in forging factory. During forging, the maximum displacement on top of the middle cylinder was measured. As shown in the following graphs (Figs. 12 and 13), both simulated and measured are comparable. All virtual simulations done on this task were achieved correctly, the model being valid.

In the virtual CAE simulation the displacement amplitude of hydraulic press during the working stroke was of 28 mm. In real measurement it was almost the same amplitude (30 mm).

For post-processing of all virtual simulations the software Siemens NX 9 was used.

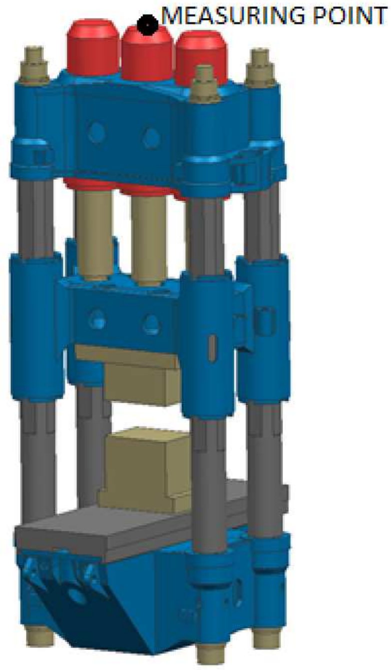

Fig. 11. Virtual model with measuring point.

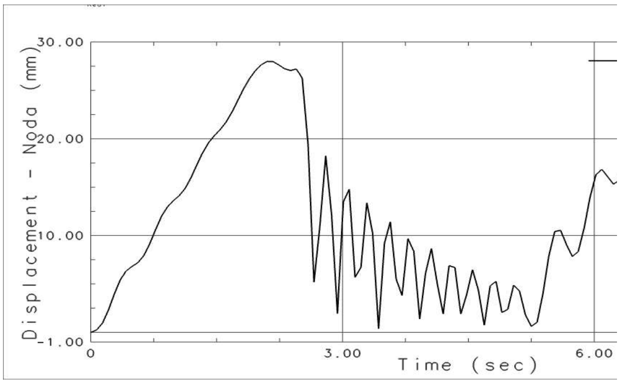

Fig. 12. Displacement in time from CAE simulation.

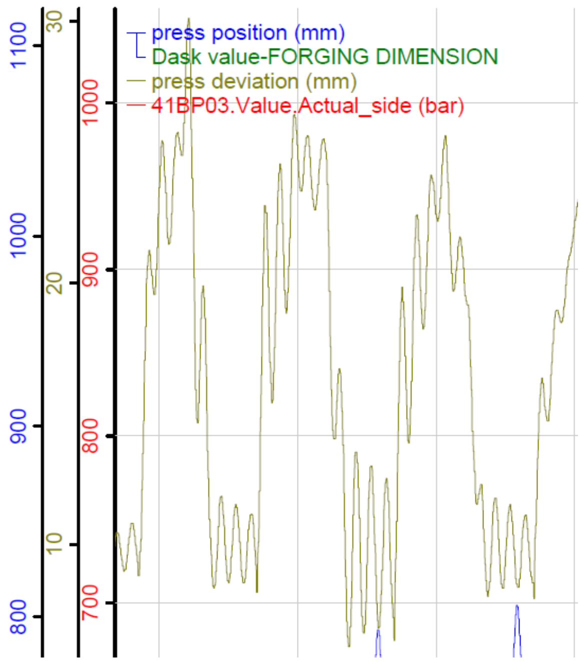

Fig. 13. Displacement in time from real experiment.

4. CONCLUSIONS

Because our research centre already improved design of the hydraulic forging press CKV 200 MN, this press was chosen as suitable for adding new multidirectional forging device. Also, the producer of this press wants to add this to the portfolio.

We have done a structural design of the multiway device and validated all simulations by comparing one of them with real measurement. The problem is that of the pressure of hydraulic cylinder (42 MPa). This pressure is not possible to fully meet the requirements of the assignment. To this device it is necessary to add pressure multiplication that leads to working pressure at least of 60 MPa. At this pressure, the diameter of cylinders and also whole multidirectional forging device can be smaller.

It is obvious that adding the multidirectional forging device will reduce the size of the working stroke of the hydraulic press.

It should also be taken into account that during multidirectional forging the columns of press are not only loaded along axis on tension, but also bended. The maximal Von-Mises stress is under maximal allowable values.

Application of multidirectional forging device is suitable for forging presses with wide distance between columns in direction perpendicular to the axis of the table.

In future, this basic design will be more precisely developed and with the aid of producer's facilities a prototype will be achieved. It would be also possible to check properties on reduced model mounted on our working educational hydraulic press. Because factories producing special forming machines are interested in this technology, research will continue and also some results will be covered by patent protection.

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REFERENCES

[1] B. Rudolf, *Tvářecí stroje* (Forming machines), České vysoké učení technické, Praha, 1979.
[2] I. Kamelander, *Tvářecí stroje II* (Forming machines II), Vysoké učení technické, Brno 1985.
[3] J. Staněk, *Základy stavby výrobních strojů: tvářecí stroje* (Basics of production machines design), Západočeská univerzita, Plzeň, 2001.
[4] S. Benča, *Riešenie nelineárnych pevnostných úloh: pomocou MKP* (Nonlinear strength tasks solving with FEM), Nakladateľstvo STU, Bratislava, 2009.
[5] M. Dvořák, F. Gajdoš, K. Novotný, *Technologie tváření: plošné a objemové tváření* (Forming technology: Volumes and sheets forming), Akademické nakladatelství CERM, Brno, 2013.
[6] M. Čechura, V. Kubec, K. Ráž, *Dynamic behavior of the hydraulic press for free forging*, Procedia Engineering-DAAAM International, Vienna, 2015.
[7] V. Kubec, K Ráž, *Using of a hydraulic press in production and manufacturing of large rings*, Procedia Engineering-DAAAM International, Vienna, 2013.

[8] Z. Chval, M. Čechura, *Optimization of power transmission on mechanical forging presses*, Procedia Engineering-DAAAM International, Vienna, 2013.

[9] H.S. Valberg, *Applied Metal Forming including FEM Analysis*, Cambridge University Press, New York, 2010.

[10] S.K. Ghosh, *CAD/CAM & FEM in Metal Working*, Oxfordshire: Pergamon Press, Oxford, 1988.

[11] S. Benča, *Výpočtové postupy MKP pri riešení lineárnych úloh mechaniky* (Algorithm of FEM simulations on linear mechanics), Vydavateľstvo STU, Bratislava, 2004.

[12] H. Tschätsch, *Metal Forming Practise: Processes – Machines – Tools*, Springer-Verlag, Berlin, 2006.

[13] R. Samek, E. Šmehlíková, Z. Lidmila, *Speciální technologie tváření* (Special forming technologies), Akademické nakladatelství CERM, Brno, 2010.

[14] V. Koloušek, *Dynamics in engineering structures*, Academia, Praha, 1973.

[15] O. Ševeček, *Řešení obecných koncentrátorů napětí v anisotropních prostředcích pomocí kombinace MKP a teorie komplexních potenciálů: zkrácená verze* (Solution of general stress concentrators in anisotropic media by combination of FEM and the complex potential theory: a shortened version), Vysoké učení v Brně, Brno, 2009.

[16] A. Gontarz, *Forming process of valve drop forging with three cavities*, Journal of Materials Processing Technology, Vol. 177, 2006, pp. 228–232.