INFLUENCE OF CROSSHEAD GUIDE TO OFF-CENTRE LOAD OF FORGING HYDRAULIC PRESS

VACLAV KUBEC, MILAN CECHURA

University of West Bohemia in Pilsen, Faculty of Mechanical Engineering, Pilsen, Czech Republic

DOI : 10.17973/MMSJ.2016_11_2016118

e-mail: vkubec@kks.zcu.cz

Off-centre loads acting on hydraulic forging presses have a major impact on their engineering properties. If the tilting moments resulting from such loads are absorbed using an appropriate and effective design, the deformation of the press frame and pressures in crosshead guides can be minimized.

The present paper compares values obtained from several variants of virtual models of an open-die forging hydraulic press under off-centre load. The objective was to evaluate the effect of the design solution of crosshead guides on the behaviour of the frame.

KEYWORDS

forging press, hydraulic press, accuracy, guides, crosshead, virtual models

1 INTRODUCTION

A majority of operations carried out in hydraulic presses for open-die forging involve off-centre loading.

The resulting forces and moments are absorbed by the machine's frame. This causes tilting of the frame, increased stress and, ultimately, low accuracy of the forging process.

The magnitudes of forces and moments associated with the operation are an invariable and fundamental aspect of the process. Therefore, the engineering designer's job is to find design solutions which best suppress the effects of the off-centre loading on the press and on its behaviour.

The main criterion is to minimize the lateral forces produced by the tilting moments on the press. This means minimizing the distortion of the machine and the pressures on its guides, leading to longer life, and, finally, better dimensional accuracy of the forged parts.

Although the moment imposed by the load will not change, the forces acting on the guides – which transmit the moment to the frame – can be reduced by setting the guide elements farther apart.

We have therefore attempted to compare several guide configurations for the crosshead of a forging press.

2 CROSSHEAD GUIDE CONFIGURATIONS

Today, there are two approaches for arranging the guides that carry operating loads:

1. The loads are carried by guides provided on the posts.

In an effort to minimize the forces acting on the posts, engineering designers strive to maximize the distance between the guides on a post. Due to the height of the working space, the potential of this arrangement is limited.

2. The loads are carried by guides on the posts plus a guide rod in a bushing mounted in the crown. This solution increases the distance between the points of application of forces on the guides but it also limits the options for controlling the press force, as it requires exactly two hydraulic work cylinders, and therefore the force cannot be varied in steps by activating 1, 2, or 3 cylinders at a time.

Nevertheless, today's hydraulic drive controls are so advanced that the method of controlling the force by activating or deactivating separate cylinders becomes irrelevant, as more modern methods are available. We have therefore decided to compare, using today's computational tools and virtual models, the engineering characteristics of both above-named approaches for absorbing the tilting moment.

2.1 Virtual models

For this investigation, we have chosen a four-post variant of the CKV hydraulic press for open-die forging with three work cylinders. In the virtual model, the machine was subjected to an off-centre force. To obtain as accurate comparison as possible, the model was only altered in one respect: by adding a guide rod at the resting point of the central cylinder. The central work cylinder was then used as its guide. For reasons related to the comparison, the variant without the guide rod did not include the plunger of the work cylinder (Fig. 1).

In order to explore the effects that the stiffness of the guide rod may have, the configuration variant which included the guide rod was divided into two sub-variants. In one of them, the guide rod had the same diameter as the central pin of the plunger of the work cylinder (Fig. 2); the moment of inertia of this guide rod cross section in bending was 0.03998 m^4. The other sub-variant (Fig. 3) involved a guide rod with a 40 % higher bending stiffness; the moment of inertia of its cross section in bending was 0.10105 m^4, i.e. 2.53 times larger.

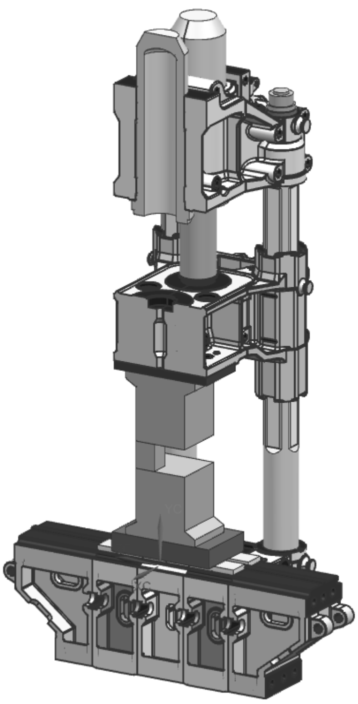


Figure 1. Configuration variant without guide rod

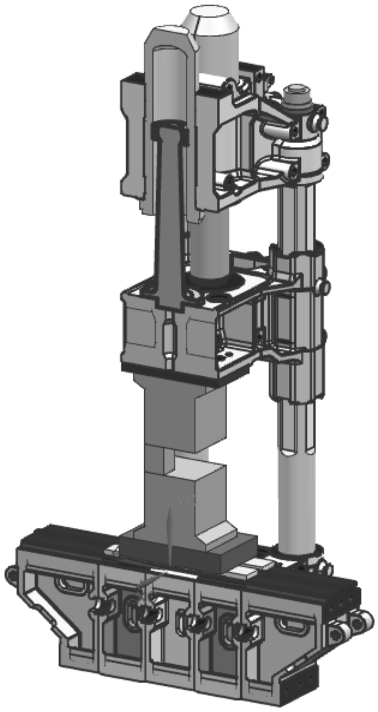


Figure 2. Configuration variant with guide rod

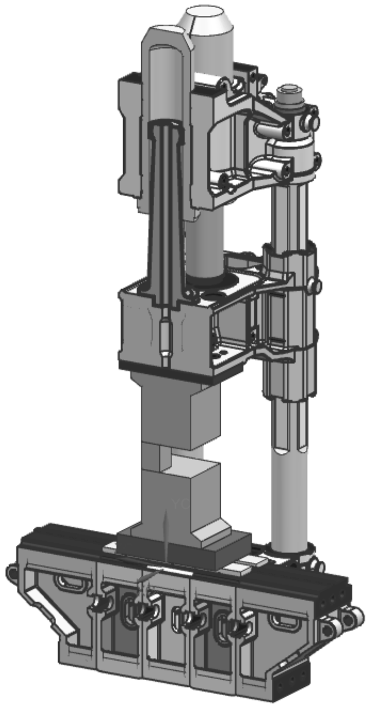


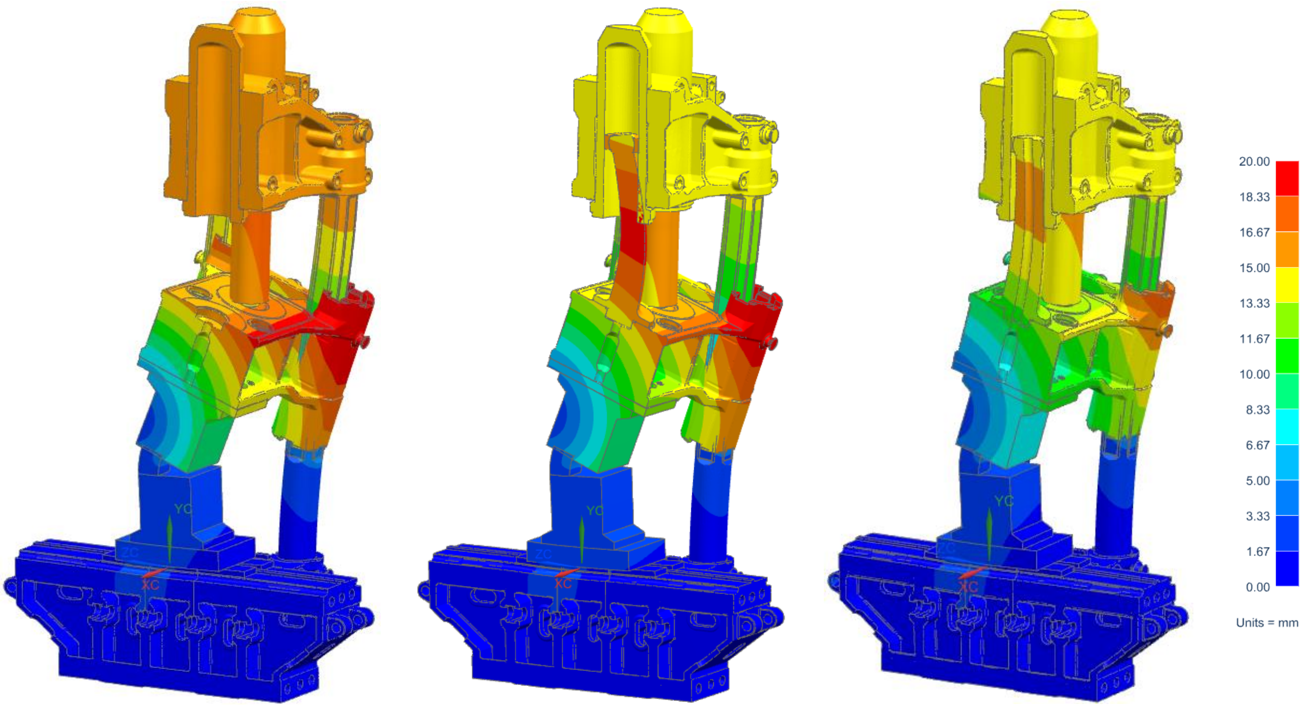
Figure 3. Configuration variant with guide rod of higher stiffness

The purpose of the virtual models was to enable the behaviour of the entire frame to be studied. Therefore, some details were omitted which would otherwise make the computation rather demanding. For instance, the connecting braces in the split crossheads and crown were omitted. In this computation, both the crown and the crossheads were taken to be single-piece structures.

2.2 Results of computations using finite element method

On these virtual models, several variables were determined on the crown and the crosshead. Identical points of measurement were used in all configuration variants. At these points, displacement readings were taken and used for calculating the resulting displacements and deformation.

Fig. 4 shows total displacements for the variant without a guide rod and for the two sub-variants with a guide rod, using a uniform scale. Even in this general view, different responses of the variants can be seen, for instance in terms of the crosshead tilt, deformation of posts and deformation of the guide rod.



a) The variant without guide rod

b) The variant with guide rod

c) The variant with guide rod of higher stiffness

Figure 4. Total displacement under off-centre load (the deformation is displayed as disproportionately large)

3 EVALUATION

In the graphs below, displacement values are plotted for the computation variants. The comparison involves displacements of the crown and the crosshead in the vertical direction, and in the lateral direction, i.e. the direction of the bolster axis. Tilt values for the crown and the crosshead were compared as well. The tilt was represented by the difference between vertical displacements at points located at edges of the top plates on the symmetry plane. The points of the virtual models at which these values were identified are shown in Fig. 5.

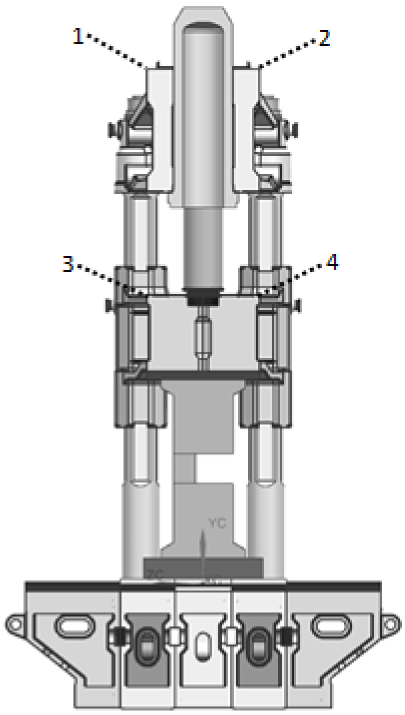


Figure 5. Identification of the points of measurement

The configuration variants for which calculations were run were as follows:
1: the variant without guide rod
2: the variant with a guide rod and contact in bottom guides
3: the variant with a guide rod of higher stiffness and contact in bottom guides

Vertical displacement values for the crown were calculated as arithmetic means from locations “1” and “2”.

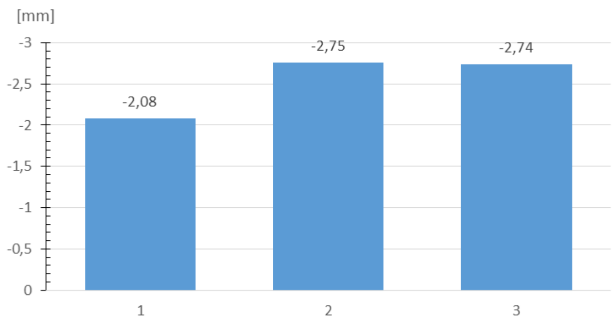


Figure 6. Vertical displacement of the crown

Displacement values in the direction of the bolster axis for the crown were calculated as arithmetic means from locations “1” and “2”.

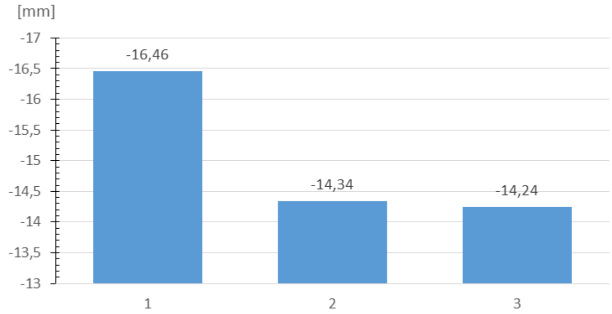


Figure 7. Lateral displacement of the crown

Tilt values for the crown were obtained as the difference between the vertical displacement values in locations “1” and “2”.

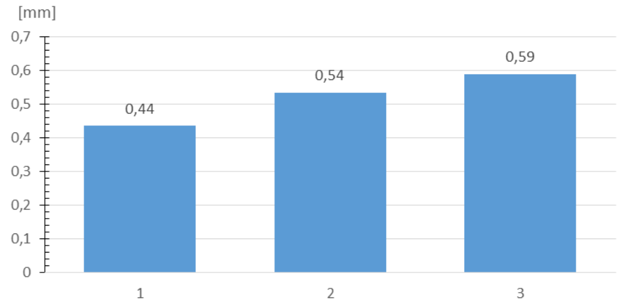


Figure 8. Tilt of the crown

Vertical displacement values for the crosshead were calculated as arithmetic means from locations “3” and “4”.

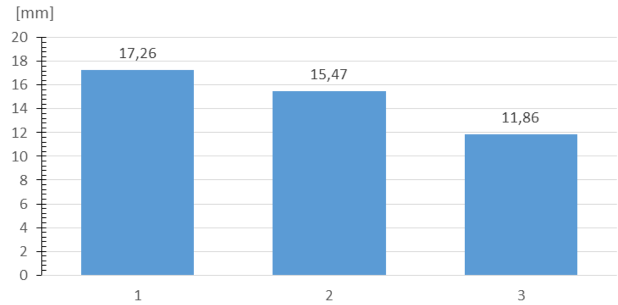


Figure 9. Vertical displacement of the crosshead

Displacement values in the direction of the bolster axis for the crosshead were calculated as arithmetic means from locations “3” and “4”.

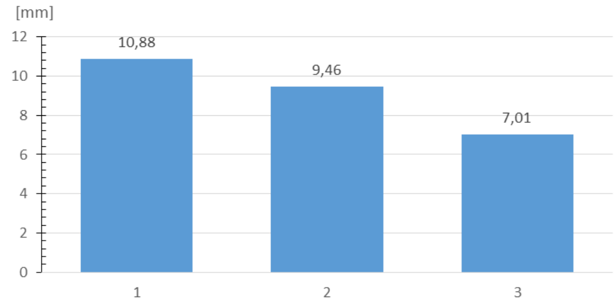


Figure 10. Lateral displacement of the crosshead

Tilt values for the crosshead were obtained as the difference between the vertical displacement values in locations “3” and “4”.

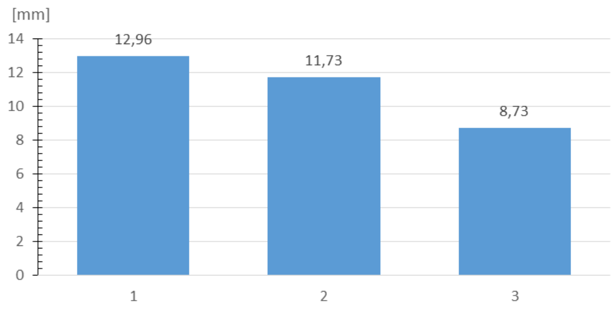


Figure 11. Tilt of the crosshead

The graphs above show displacements found in the individual configuration variants which give a picture of their deformation behaviour.

4 CONCLUSION

Eliminating the tilt of the plunger crosshead by means of a guide rod is a concept which was used by the Krupp company as early as in the 1930s, in their special-purpose press for bending armour plates where, rather than force control, the parallelism of dies during operation was of importance. With general-purpose open-die forging presses, more importance was attached to achieving zero-loss capability of force variation than to guiding the plunger crosshead accurately.

Today, as hydraulic drives provide infinitely adjustable force without the need for stepper drives, the authors have set to explore – using virtual modelling capabilities – the potential for reviving the guide rod concept (as a rather effective method of controlling the tilting moment in off-centre forging processes) as a competition to the current widely used method of absorbing the tilting moment by the posts alone.

To the user, the important aspect is the shape accuracy of the forged product, which is conditional on the stability of the plunger crosshead and the tool attached to it.

In this respect, Figs. 9, 10, and 11 are those of importance among the graphs shown here.

The outcomes are clearly more favourable in the presses that feature the guide rod than in the present-day ones with guides on posts. It is also evident that the guide rod stiffness plays a great role in the resulting tilt (as shown by the results for variants 2 and 3: an increase in stiffness does not necessarily mean larger weight).

This study has conclusively shown that the nowadays disregarded design solution with a guide rod in hydraulic presses for open-die forging can provide – when combined with the added advantage of advanced zero-loss control systems – better guiding accuracy than today’s ordinary hydraulic press configurations.

Moreover, one should not forget that with much lesser forces to sustain, the guides will have longer life, and will require less maintenance costs and less frequent adjustment. Accordingly, the life of the entire press becomes longer as well, as the stresses in its severely loaded locations are reduced.

All these aspects contribute to the quality and competitiveness of the product.

Thanks to the power of virtual modelling, the present paper shows how a combination of well-proven old principles and new capabilities of hydraulic drives can further enhance the quality of a particular machine.

Now, it is up to press manufacturers to consider these findings for application and up to users to raise their demands for manufacturing equipment and put pressure on their producers to implement recommendations of this kind.

ACKNOWLEDGMENTS

This article was done by financial support of TA CR – project TE01020075 and also by financial support of the institutional funding for long-term strategic development of the University of West Bohemia provided by the Ministry of Education of the Czech Republic.

REFERENCES

Manufacturers’ documentation

[Cechura 1999] Cechura, M., Stanek, J. Forming machines: hydraulic presses (Tvareci stroje: hydraulicke lisy in Czech). Plzen: University of West Bohemia, 1999. ISBN 80-7082-480-8

[Cechura 2011] Cechura, M., Kubec, V., Raz, K., Stanek, J., Chval, Z. Monitoring functions and properties of forming machine (Monitorovani funkci a vlastnosti tvarecich stroju in Czech). ZCU v Plzni, research report, 2011.

[Kubec 2012] Kubec, V., Cechura, M., Raz, K. Monitoring of large hydraulic presses for open die forging. Kovarenstvi, Vol. 2012, No. 44, pp. 85-88. ISSN: 1213-9289

CONTACTS

Ing. Vaclav Kubec, Ph.D.
University of West Bohemia, Faculty of Mechanical Engineering
Univerzitni 22, Plzen, 306 14, Czech Republic
Tel.: +420377638256
e-mail: vkubec@kks.zcu.cz