Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 69 (2014) 1070 – 1075

Procedia Engineering

www.elsevier.com/locate/procedia

24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013

Modal Analysis of Hydraulic Press Frames for Open Die Forging

Martin Zahalka*

University of West Bohemia, Faculty of Mechanical Engineering, Department of Machine Design, Univerzitni 8, 306 14 Pilsen, Czech Republic

Abstract

Dynamic behavior of the forging machines is necessary to explore due to the increasing of speeds on large forging hydraulic presses for open die forging. The paper describes the modal analysis of two selected presses, which represent the most common designs of hydraulic presses for forging. The first press is with double-column frame CKV 50 with the force 50MN and the second one is with four-column frame CKV 170 with the force 170 MN. Further are described the simulations of oscillation, which was excited by time-dependent work force. Results of analysis are compared with measurement in the real operation.

Selection and peer-review under responsibility of DAAAM International Vienna

Keywords: forming machines, hydraulic forging press, modal analysis, FEM simulation

1. Introduction

The requirement for the examination of the dynamic behavior of the hydraulic presses resulted from the cooperation of CVTS (Research Centre of the Forming Machines Design) at UWB in Pilsen with TS Plzen. This area of calculations in large forming machines was not important in the past. Due to the low speeds and low stroke frequencies it was not necessary to examine the dynamic behavior of these constructions.

Literature dealing with dynamic behavior of these forging machines is not prepared because it is a new problem that occur in area of forging machines.

Because cases of uncontrolled oscillation of forging machines becomes more frequent in real operation. With the increasing speeds of large hydraulic presses, it is becoming necessary to explore the dynamic behavior of the machines. [8] The necessary condition is that the stroke frequencies of the press (depending on the speed of forging) must be at sufficient distance from natural frequency oscillations of the press.

* Corresponding author. Tel.: +420-377 638 229;
E-mail address: martinza@kks.zcu.cz

Selection and peer-review under responsibility of DAAAM International Vienna
doi:10.1016/j.proeng.2014.03.092

For these reasons modal analysis of two selected press frames were performed. The first press was with a two-column frame with a power of 50 MN and the second one was with a four-column frame with a power of 170 MN. [1]

Further simulations were performed with excited oscillation. Excitation was made by harmonic loads and loads which simulated the press working cycle. The results were compared with measurements in real operation. [2]

2. Hydraulic forging presses CKV 45/50 MN, CKV 140/170 MN

The two types of presses for which were made modal analysis are shown in the following pictures.

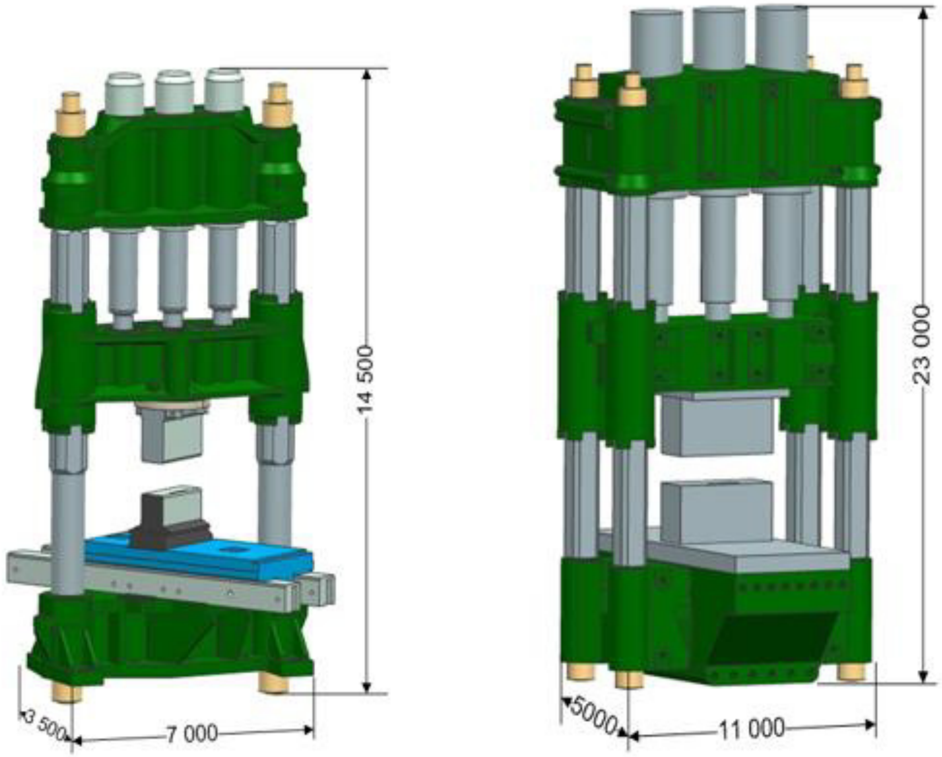

Fig. 1. (a) Hydraulic forging press CKV 45/50 MN, (b) Hydraulic forging press CKV 140/170 MN.

3. Comparison of the first natural frequencies

When the modal analyses of these presses were performed, was found that the natural frequency is close to 2 Hz. This could be an indicator of a relatively small stiffness of these press frames. Although the stiffness is comparable to current operated presses, frequencies of forging reach a value of 100-120 strokes per minute. So we can see that the press frames can easily get to the area of resonance. [3, 4]

From both presses which were solved is, as expected, slightly stiffer a four-column press, which has the first natural frequency 2.24 Hz compared with a two-column press with natural frequency 2.03 Hz.

The shapes of the first own oscillations are in both variants, due to the different construction of frames, slightly different. This is caused by placement of columns. The two-column frame hasn't comparable high stiffness in the perpendicular direction to the join of columns. Mode shapes at the first natural frequencies are shown in the following figures 2a and 2b.

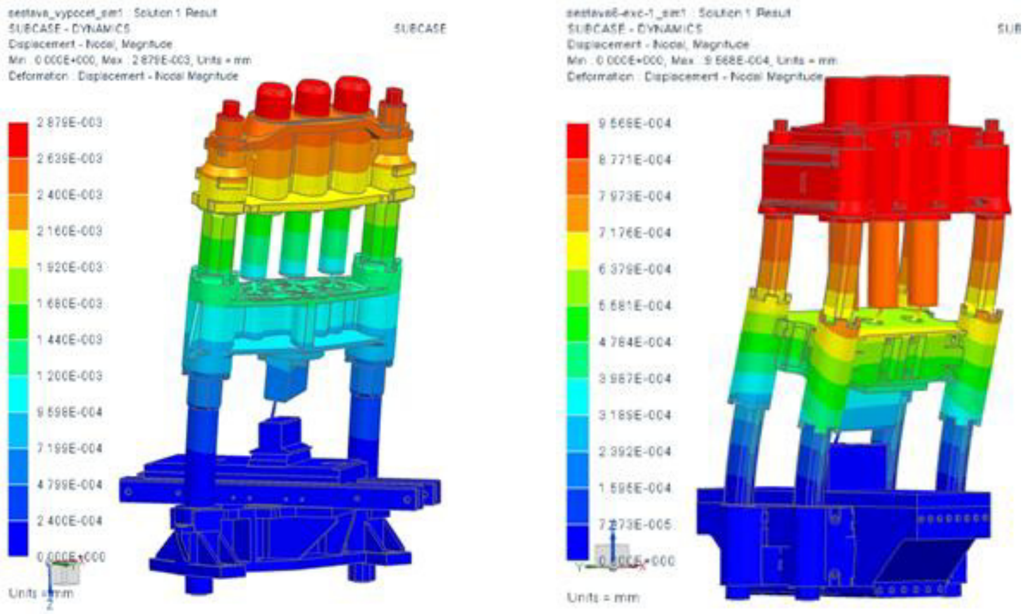

Fig. 2. The first modes of oscillation (a) CKV 45/50 MN, (b) CKV 140/170 MN.

4. Analysis with time-dependent force

The loading frequency was specified using frequencies from real operation, due to the possibility of further comparison of results. The variable loading was based on the changes of pressure in the press cylinders. The time dependence of the pressure is shown in the figure 3 below. The press is loaded continuously from a resting position for 2 seconds at maximum power 45 MN at two-column press and 140 MN at four-column one. A short delay and unloading follow at this value, as shown in figure 3.

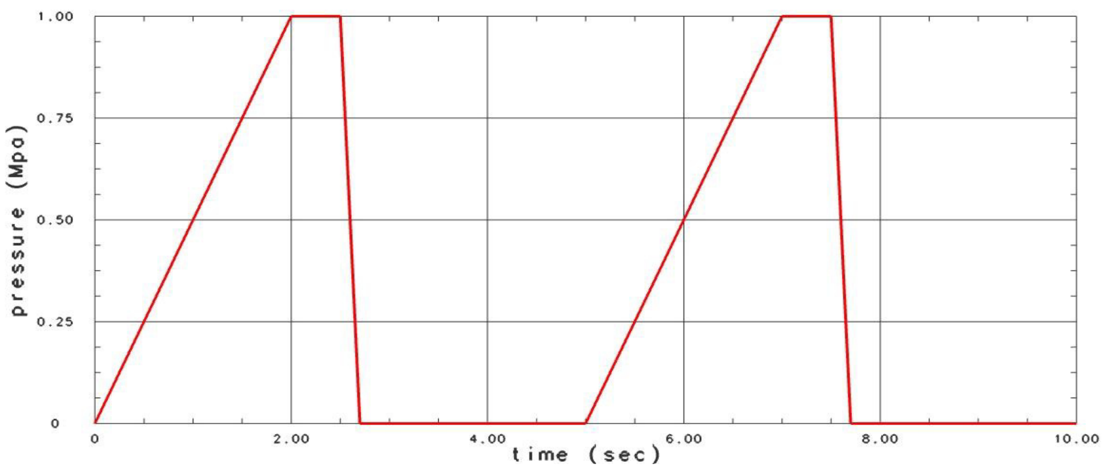

Fig. 3. Time-dependence of the pressure in the cylinders.

The deflection of press was read at the same place in both variants. It was the centre of the base surface of the middle working cylinder. The place, where the measurement in the real operation was made, was the same. The following figures plot the time dependence of the displacement ot a two-column and a four-column press frame. Values show total deflection including extension of press frame.

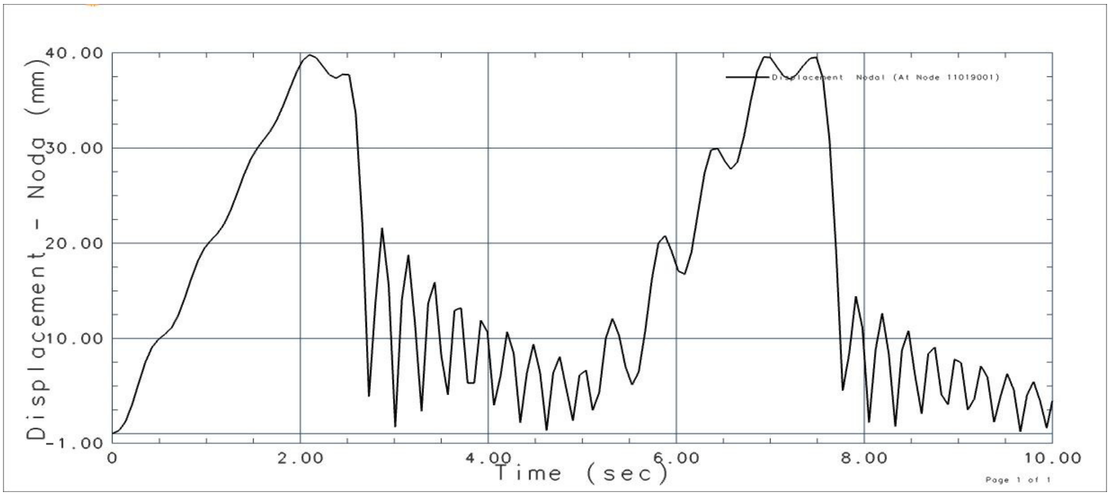

Fig. 4 Time-dependence of displacement for two-column press.

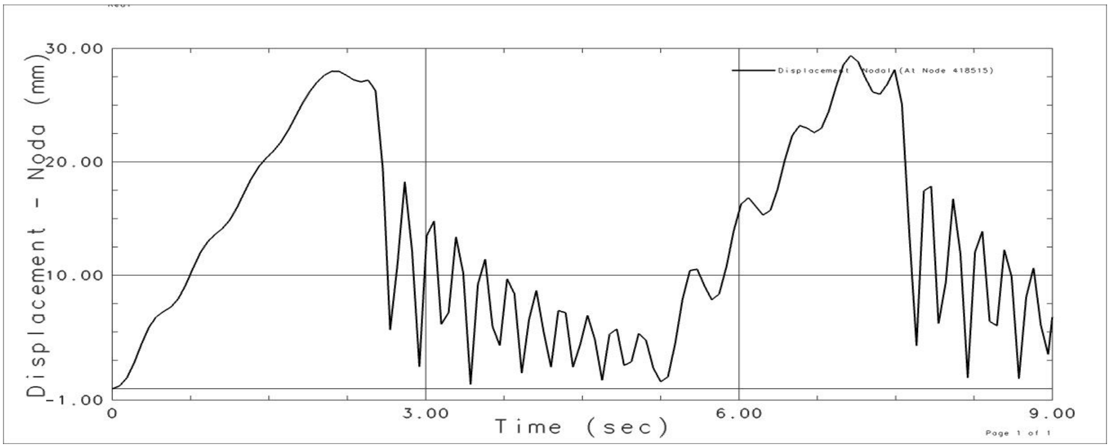

Fig. 5 Time-dependence of displacement for four two-column press.

The deflection curves for the two-column and four-column press are not very different from each other in this case.

The previous figures 4 and 5 show the differences in the displacement at the first and the second press load too (first and second work cycle). Press is loaded from a resting position at the time 0s to the time 2 seconds. Loading is followed by a short delay and unloading, which is shown in the figure 4. This relatively fast unloading cause oscillation of structure, as it is shown in figures 4 and 5, after the time 2.5 sec. The press is loaded again at the time 5s. Loading in the second working cycle does not start from a resting position, but from the current situation that has been excited in the previous working cycle. This causes a difference in the course of deflection in the first and second loading cycle. The second cycle is closer to reality.

5. Comparison of boundary conditions for modal analysis

Comparing of the boundary condition influence on the quality of the results (obtained natural frequency) was performed before starting calculation of modal analysis. Several variants of computational models were made, from the simplest model, in which the frame was considered only in the form of lower and upper girders and columns, to a model in which were considered plungers and anvils. Selected computational models are shown in figure 6 and 7.

The calculation model which is shown in Figure 6 on the left has the natural frequency 2.5 Hz. In the model on the right was to the previous computational model added plungers into the cylinders. The larger mass insert in the upper girders caused the expected reduction of the natural frequency by 0.1 Hz to 2.4 Hz.

In the final calculation model, which is shown in figure 7 are not neglected any high mass structures that could affect the natural frequency. The value of the frequency was calculated to be 2 Hz. Compared to the initial calculation, there was a decline in the value of the natural frequency by 0.5 Hz.

Fig. 6. The initial computational models.

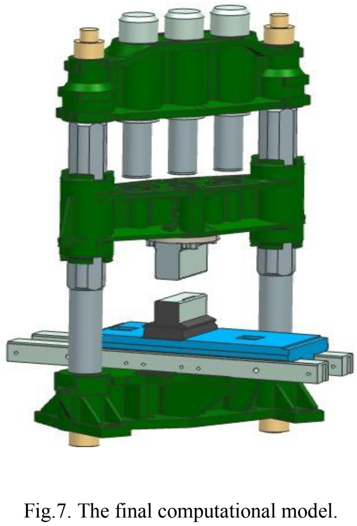

Fig.7. The final computational model.

6. Conclusion

That it is necessary to deal with these problems is evident from the obtained results of performed modal analysis on the presses CKV 50 and CKV 170. [6] Because the number of strokes reaches a value despite of 2 Hz, the excitation frequency approaches to the real natural frequency of press frame. The task of the designers is to design press frames with high usage of material and the greatest material savings at the proposed design solution. [7]

$$\Omega = \sqrt{\frac{c}{m}}$$

This is in contrast with the requirement for increasing of the natural frequency of the press frame, where:
Ω - natural frequency of the structure, m - weight of the structure, c - stiffness,
Greater mass means lower natural frequency and conversely.

This problem can be partly eliminated that the designers try, if possible, to increase the stiffness of the structure, without any increase of weight. We have very limited possibilities in this case.

One possibility of increasing stiffness is change the column shape as is shown in the right figure 8. The columns are the least stiff part of these press constructions. We can get higher second moment of area with the same area of cross section by changing of shape only. It can be the way of further research.

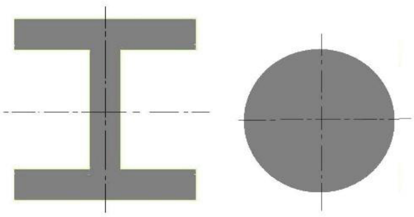

Fig. 8. “H” column in comparison with circle.

The results of performed calculations were verified by comparison with the measured results from the real work of the press. [2] The only one problem of the numerical simulation is determination of damping coefficient of the structure which is necessary to enter into the calculation. [5]

We can say that our simulations are in accordance to reality.

References

[1] Company literature of TS Plzen a.s.
[2] M. Cechura, J. Hlavac, J. Kubec, Functions and features monitoring of forming machines, V-10-091, VSCVTT, Prague, 2010.
[3] M. Cechura, Z. Chval, Kovarenstvi. Convectional versus multiple operating press, May 2013/17, 67-70, ISSN 1213-9289, Brno, 2013.
[4] V. Kubec, K. Raz, Two-columns versus four-columns hydraulic press, Kovarenstvi, May 2013/17, 67-70, ISSN 1213-9289, Brno, 2013.
[5] Siemens PLM, NX 8.5 Documentation, 2012.
[6] M. Cechura, J. Smolik, Development Of New And Innovations Of Existing Construction Solutions Of Forming Machines, research report, CK-SVT-WP11, CVTS, Pilsen, 2012.
[7] Z. Chval, Reducing material costs and effect of heat load of forming machines, Ph.D. Dissertation, University of West Bohemia, 2011.
[8] Cechura, M.; Kubec, V.; Raz, K. Analysis of the current situation in the field of hydraulic presses (above 50 MN), Pilsen : ZČU, 2009.