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Dynamic Behavior of the Hydraulic Press for Free Forging

Karel Raz*, Vaclav Kubec, Milan Cechura

University of West Bohemia, Faculty of Mechanical Engineering, Regional Technological Institute, Univerzitni 8, 306 14 Pilsen, Czech Republic

Abstract

Work on hydraulic presses is defined by a static forging force. This force may have in special cases of forging properties of dynamic and shock load. Commonly used hydraulic presses can use speed-forging with speed up to 180 strokes per minute. Our goal is to compare different types of frame designs used for hydraulic forging presses. Result is determination of the suitability of each supporting structures for these special operations. Comparing is made using FEM modal analysis. The performed modal analysis show needs for lowering of first critical natural frequency. An overview of these frequencies is shown in attached tables.

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1. Main Text

The task of every research group is to solve their research topics at least one step ahead of the current needs of the industry.

This is connected with prediction of development in this area. As part of the University of West Bohemia in Pilsen, we tried in advance to deal with it. In cooperation with industry we tried to find tasks in the field of metal forming machines.

Dynamic behaviour is one of the key problems in the design of hydraulic presses for free forging.

This topic is relevant because customer needs hydraulic press for forging with higher number of strokes per minute. Different designs of hydraulic presses were not compared seriously up to now. We decided to perform monitoring of individual design options, and then make precise modal analysis. This analysis is done on individual

* Corresponding author. Tel.: +42-037-763-8254.

E-mail address: kraz@rti.zcu.cz

types of designs of hydraulic forging presses. This virtual simulation will show us basic dynamic behaviour of free forging presses design. Currently is in industry commonly used design of hydraulic forging presses with top drive, two-column or four-column, or with lower drive with two-column or four-column.

For analysis were chosen presses with comparable properties (size, force). Conditions for the analysis and the results of the analysis are in the following article.

2. Hydraulic free forging presses

The actual trend is to use the presses up to their maximum specification (maximal force, maximal count of strokes per minute). Generally are free forging operations (upsetting...) using calm force (no fast changes of force). During monitoring of hydraulic press's lifetime and technological operations, we realized that for some technological operations this is not true.

One of the operations during which is press dynamically loaded is high-speed forging (up to 180 strokes per minute).

For comparison purposes, we used a hydraulic presses with a different structural design of the frame, but with equivalent technological parameters. Main technological parameters, which are considered are forging force and maximum size of forged piece. Force is 50 MN, the space between columns in a direction perpendicular to the machine axis is four meters.

The proposed structural variants are comparable in terms of maximal stress in structure. Maximal difference in stress between same parts in all presses is less than 10%. The Von-Misses stress in all designs of presses are in the range of 50 to 75 MPa depending on the actual load condition (upsetting, lengthening...).

For comparison were chosen four typical hydraulic press designs. [1, 2, 3]

Hydraulic press 1 (Fig.1 a) Press with four-column frame and top drive. It has pre-stressed rectangular columns and beams are designed as castings from one piece.

Hydraulic press 2 (Fig.1 b) Press with two-column frame and top drive. It has pre-stressed rectangular columns and beams are designed as castings from one piece.

Hydraulic press 3 (Fig.2 a) Press with two-column frame and bottom drive. It has pre-stressed rectangular columns (both with two anchors) and beams are designed as castings from one piece.

Hydraulic press 4 (Fig.2 b) Press with two-column frame and top drive. It has pre-stressed rectangular columns (both with eight anchors) and beams are designed as castings from one piece. Columns have open profile from one side.

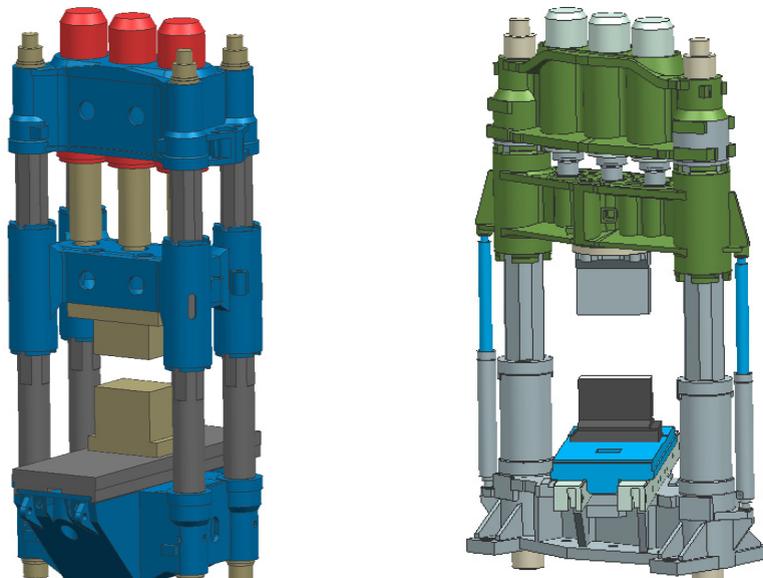


Fig. 1. a,b Hydraulic press 1 and 2.

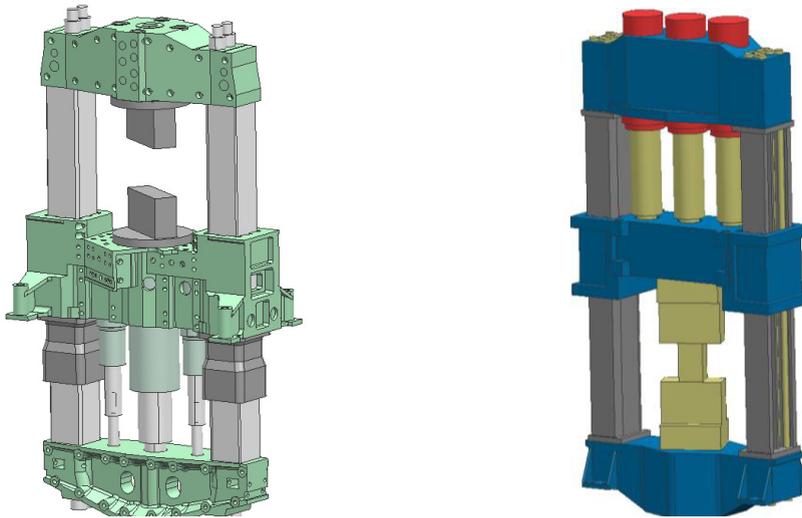


Fig. 2. a,b Hydraulic press 3 and 4.

3. Modal analysis

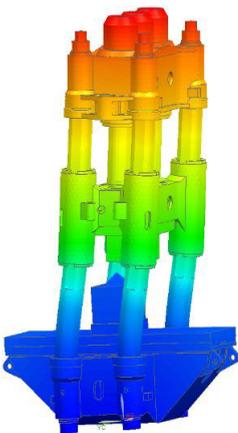
For these designs of hydraulic presses, we prepared a virtual models, which includes all the important parts of the frame (columns, anchor nuts, working cylinders, plungers). Movable members (movable crossbeam) are in a defined position, which is based on the common dimension of forged piece at these large hydraulic presses.

To include all influences was into FEM model added 0D element (point) [7, 8] with mass property equal to mass of working liquid. The simulation includes definitions of contacts in areas of relative motion of the parts. Among lower and upper anvil is defined boundary condition which allows their movement in horizontal direction. Other directions of deformation were among both anvils coupled.

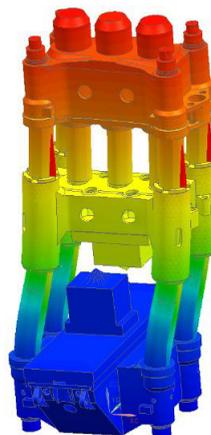
Before evaluation of the frequency was done static calculation, which gives results of initial state of pre-stressed frame. The results of this calculation were then used as input conditions for modal analysis. [4, 5, 6]

3.1. Press1

First modal shape 6,496 Hz



Second modal shape 7,955 Hz



Third modal shape 11,208 Hz

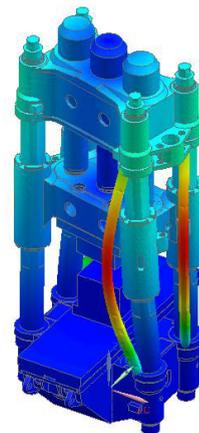
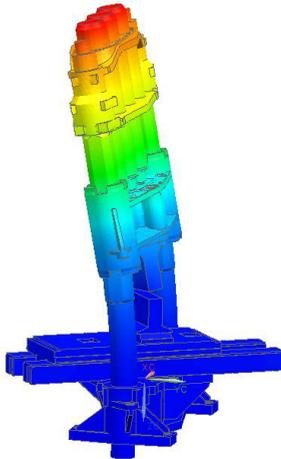


Fig. 3. Modal shapes- press1.

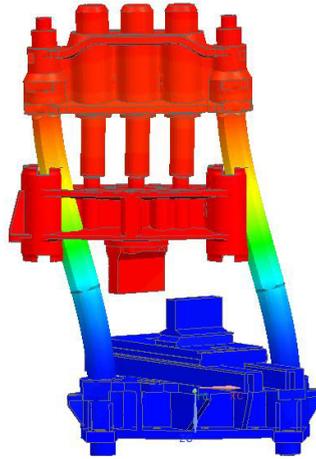
Fig. 5 shows first three modal shapes for hydraulic press with pre-stressed four-column frame and upper drive. First modal shape (6,496 Hz) corresponds to moving of the press in the direction of the axis of the press table. Second modal shape (7,955 Hz) corresponds to moving of the press in a direction perpendicular to the axis of the table. Third modal shape (11,208 Hz) corresponds to twist around the vertical machines axis.

3.2. Press2

First modal shape 2,112 Hz



Second modal shape 3,893 Hz



Third modal shape 6,680 Hz

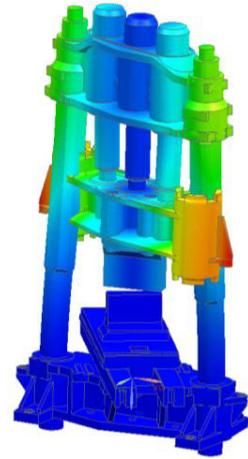
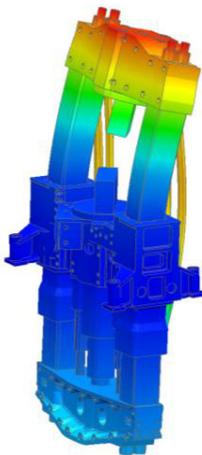


Fig. 4. Modal shapes- press2.

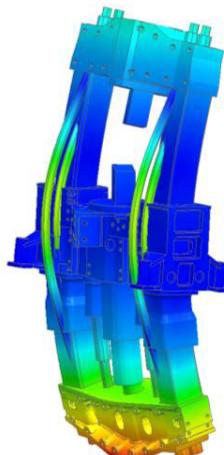
Fig. 6 shows first three modal shapes for hydraulic press with pre-stressed two-column frame and upper drive. First modal shape (2,112 Hz) corresponds to moving of the press in the direction of the axis of the press table. Second modal shape (3,893 Hz) corresponds to moving of the press in a direction perpendicular to the axis of the table. Third modal shape (6,680 Hz) corresponds to twist around the vertical axis machines.

3.3. Press3

First modal shape 7,615 Hz



Second modal shape 12,644 Hz



Third modal shape 14,262 Hz

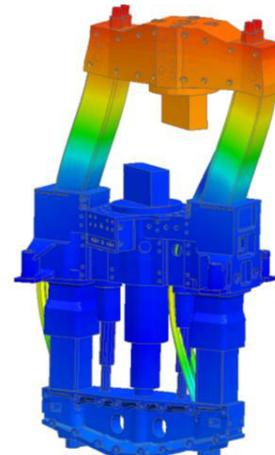
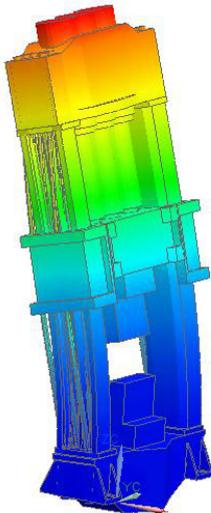


Fig. 5. Modal shapes- press3.

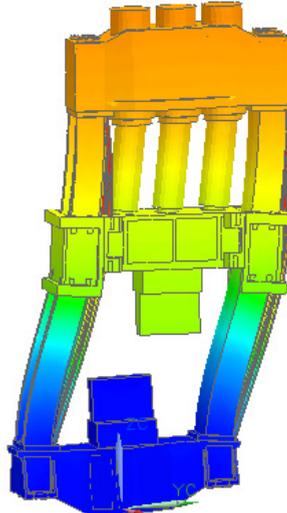
Fig. 7 shows first three modal shapes for hydraulic press with pre-stressed two-column frame and bottom drive. First modal shape (7,615 Hz) corresponds to moving of the press in the direction perpendicular to the crossbeam's orientation. Second modal shape (12,644 Hz) corresponds to moving of the press in the direction of the crossbeams. Third modal shape (14,262 Hz) corresponds to moving of upper part of press.

3.4 Press4

First modal shape 2,760 Hz



Second modal shape 4,682 Hz



Third modal shape 6,794 Hz

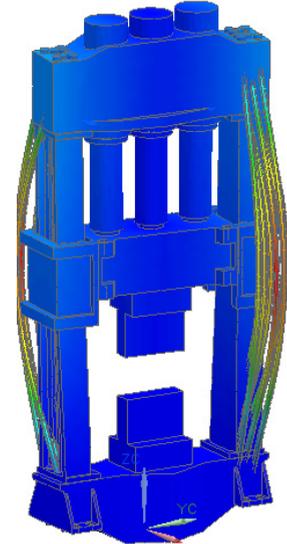


Fig.6 Modal shapes- press4

Fig. 8 shows first three modal shapes for hydraulic press with pre-stressed two-column frame and upper drive. First modal shape (2,760 Hz) corresponds to moving of the press in the direction of the axis of the press table. Second modal shape (4,682 Hz) corresponds to moving of the press in the direction of the perpendicular to axis of the press table. Third modal shape (6,749 Hz) corresponds to vibrating of anchors.

4. Summary

In tab.1 is comparing of first natural frequencies for all designs of hydraulic press. It show us toughness of all designs and it is suitable for designers during design process.

Table 1. First natural frequencies.

Press type	First natural frequency
Press 1	6,5 Hz
Press 2	2,1 Hz
Press 3	7,6 Hz
Press 4	2,8 Hz

Frequently discussed question is also influence of model size on modal shapes. When considering one design of hydraulic press we made the same one, but with bigger (using scale function).

To determine the effect of the size of a hydraulic press at a frequency was chosen hydraulic press design with four-column frame and with top drive (force 50 MN and 90 MN). The first natural frequency 6,496 Hz was published for press with force 50 MN. Same press design with nominal forging force 90 MN has first natural frequency 5,202 Hz. A smaller version of the same press is therefore stiffer.

The performed modal analysis show needs for lowering of first critical natural frequency. An overview of these frequencies is shown in a table 1.

The results show following: When trying to perform press design for optimal material utilization (comparable stress in individual structural nodes) four-column design have natural frequency of the press 5 - 6.5 Hz, two-columns presses have first natural frequency 2-3 Hz.

Hydraulic press with rectangular columns and bottom drive has first natural frequency 7.6 Hz. It is possible to design new hydraulic press for free forging with four-column design and bottom-drive. This press will have probably first natural frequency over 8Hz.

Commonly used hydraulic presses can use speed-forging with speed up to 180 strokes per minute. It is not recommended use two-column design. Best is combination of four-column design and bottom drive.

Our plans for future are to try improve design of high speed forging hydraulic press. When we can consider knowledge of modal shapes, we can design more accurate press. Also is possible to analyse other types of high speed forging presses and make conclusion, which will help customers to buy best one.

Acknowledgements

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