

INFLUENCE OF HYDRAULIC PRESS COLUMNS CONNECTION ON DYNAMIC PROPERTIES

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This paper deals with possibilities of hydraulic press design optimization. Dynamical loading is deeply discussed here. Technological operation called high speed forging is often used on this kind of machines. This technology leads to vibrations of whole hydraulic press. It must be ensured, that the lowest natural frequency of the whole press is higher comparing with frequency of forging. In research was performed finite element analysis, which showed influence of design modifications.

KEYWORDS

hydraulic press, forging, modal analysis, columns, frequency, finite element method

1 INTRODUCTION

The emphasis is today on maximal productivity. It is resulting in higher frequency of strokes during forging process. Dynamics in area of forging machines has to be solved because of that. Research on this topic was performed during previous years on University of West Bohemia in Pilsen, especially on Research Centre of Forming Machines. It was published as "Dynamic Behavior of the Hydraulic Press for Free Forging". Possibilities of computational hardware and software are now on higher level and it is possible to elaborate this topic more deeply.

Operations which needs frequencies up to 2 Hz can be used during free forging (open die forging). It means operations with 120 strokes per minute [Kubec 2014]. If any device has to work without problems, is necessary to work with frequencies at lower level than resonance frequencies. It can lead to destruction of any part or entire machine when resonance occur. It is therefore necessary to find possibilities, how increase these modal (resonant) frequencies of structure. Following possibilities of modal frequencies influencing were considered during research:

- Change geometrical shape
- Change of structure preload

Big geometrical changes are very limited because of technological specification applied on hydraulic press dimensions and their shapes. This leads to second mentioned possibility- preload change. This can be nowadays better simulated because of development in field of software solutions. Possibilities of contacts, considered in modal analysis, are more deeply described in following chapters.

Diameter of columns can be increased in geometrical optimization. This leads to better vibration resistance. This approach is in direct contrast with trends of recent times. It means that all designs have to be optimized in terms of material usage and minimal weight [Cechura et al. 2011].

Free forging press with two columns was used as an example for mentioned analysis. Forging space of two-columns press in time of forging is visible in Fig. 1.



Figure 1. View inside working space of hydraulic press with two columns

2 SIMULATION OF DYNAMIC RESPONSE OF STRUCTURES

Simulation of dynamic behaviour is divided into two steps from computational point of view:

Static analysis is performed firstly in order to get contact pressures. Modal analysis follows after that. Contact pressures are used from previous static analysis

Modal analysis can be described mathematically as solving of motion equation (1):

$$[M] \{a\} + [C] \{v\} + [K] \{q\} = \{f\}, \text{ where:} \quad (1)$$

[M]- mass matrix
[C]- damping matrix
[K]- stiffness matrix
{f}- input forces matrix
{q}- displacement
{v}- velocity
{a}- acceleration

This equation is solved by specialized software with usage of modern computational device and it is not necessary to deal with it here. Software product Siemens NX 10 with external solver NX Nastran was used during research.

All clearances were set to zero in 3D simulation model and press connection to the basement was considered as absolutely rigid. This approach is close to reality. Result without considering connection of press to the basement (during modal analysis) is also published as an interesting result. Comparing of these both results shows importance of proper boundary conditions choice.

Press with two columns was chosen for analysis. It is because is more pliable comparing with four columns press [Cechura 1999]. Results from this analysis can be fully applied also to four columns press.

Not only main modes visible by eye are evaluated during research. Focus is also on vibrations of anchors. This kind of oscillations is not visible and user doesn't know about them. It leads to higher stress in anchors and nuts. They have to be designed with respect to this conditions, otherwise rupture can occur.

3 MODAL ANALYSIS SIMULATIONS WITH CONSIDERING RIGID CONNECTION TO BASEMENT

Results are closer to reality when is considered absolutely rigid connection of press with basement. Fixing of FEM simulation model is described in following picture (Fig. 2). This fixing points (especially their stiffness) have significant influence on results. It is visible from mentioned simulation without considering this fixing.

3.1 Variant with rigid connection to the basement

Reference state was created in this simulation for comparing with other variants. Values of eigenvalue frequencies are compared.

CKV type of press with upper drive and maximal upsetting force 50 MN is considered. Pitch between columns is 5900mm and maximal stroke is 2500mm. Weight is one of most important parameters for modal analysis. This press weighs approximately 700 tons.

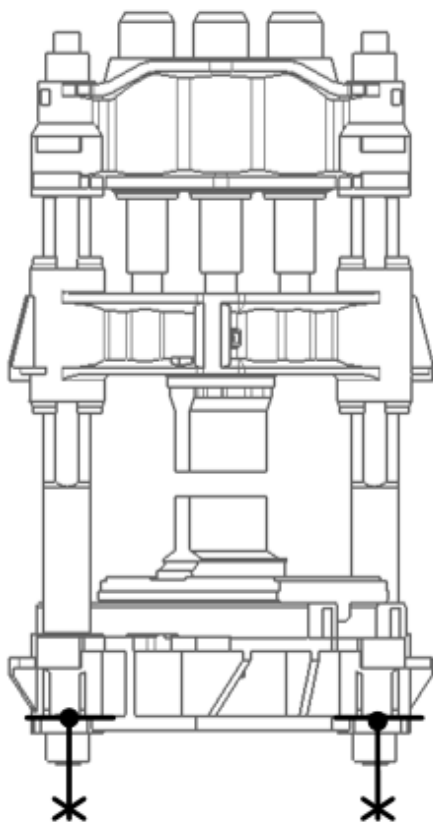


Figure 2. Schematically described fixing of pressure for modal analysis
Connection of columns to lower crossbeam with dimensions is obvious in Fig.3.

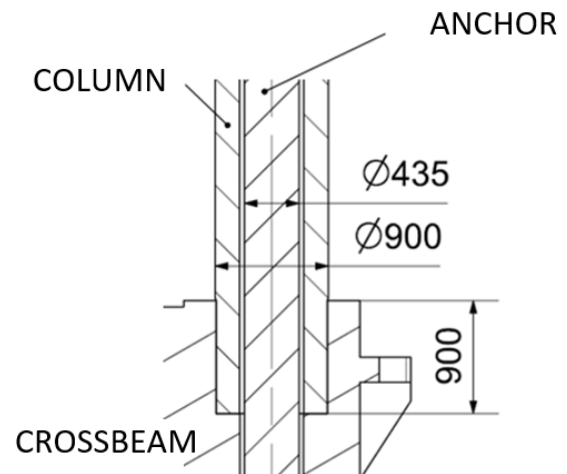


Figure 3. Initial design of connection between column and crossbeam

Modes of oscillations are visible in Fig. 4 and Fig. 5. Magnitude of deformation depends on applied driving force. Graphical results are not published for following simulations in this paper because modal shapes are still same. Changes are only in frequencies of modal oscillation. These frequencies are written and described for all simulations.

- Oscillations of anchors: 14.132; 14.231 Hz
- The lowest frequency of press: 2.164 Hz, next is modal bending at 5.837 Hz

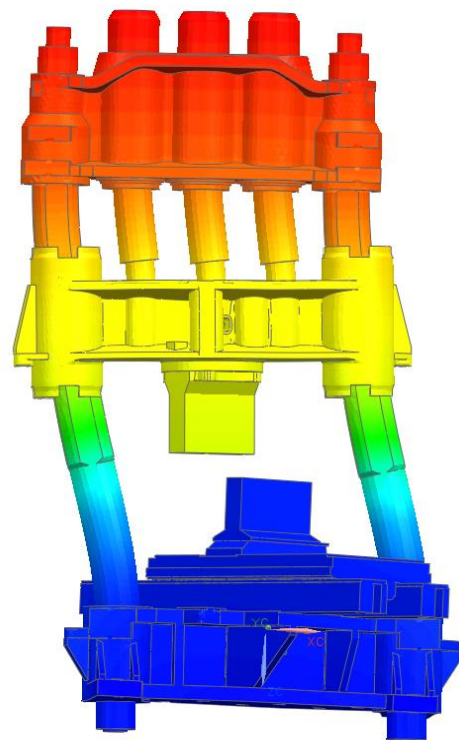


Figure 4. First modal shape with consideration of rigid connection to the basement

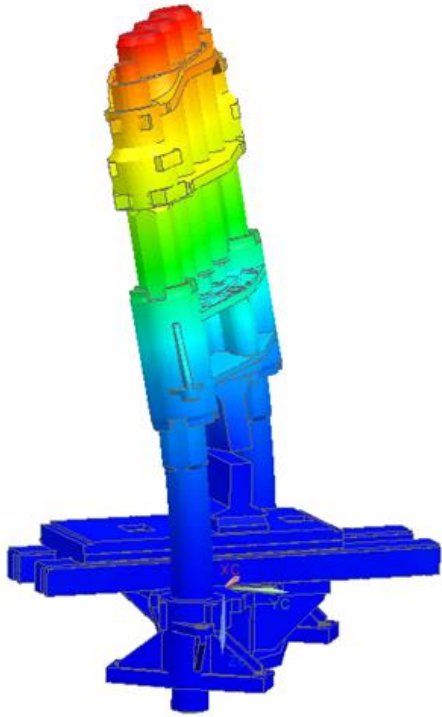


Figure 5. Second modal shape with consideration of rigid connection to the basement

3.2 Design with added collars on columns connected to lower crossbeam

Geometrical way how to improve response on dynamic loading is creating design with higher stiffness in direction of modal oscillations.

Column is a part with lower stiffness, comparing with crossbeams. This is also obvious from modal shapes, where first modal shapes are results of columns bending. This is reason of collar adding. It will lead to improving of dynamical properties (See Fig. 6 and 7). Influence of collars is obvious from results, which are shown below.

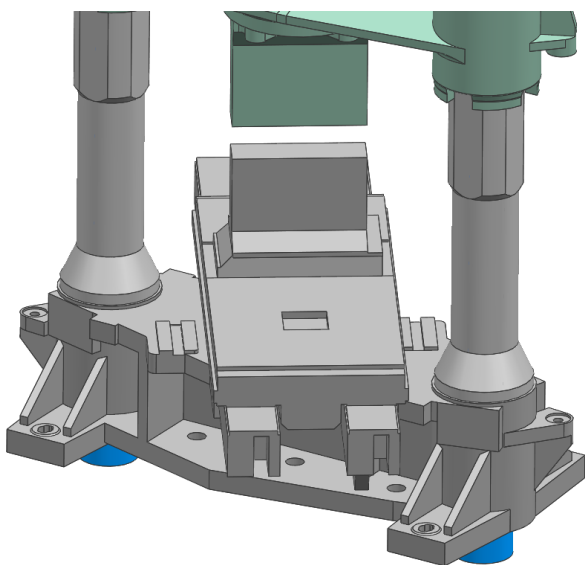


Figure 6. Working space of hydraulic press with collars

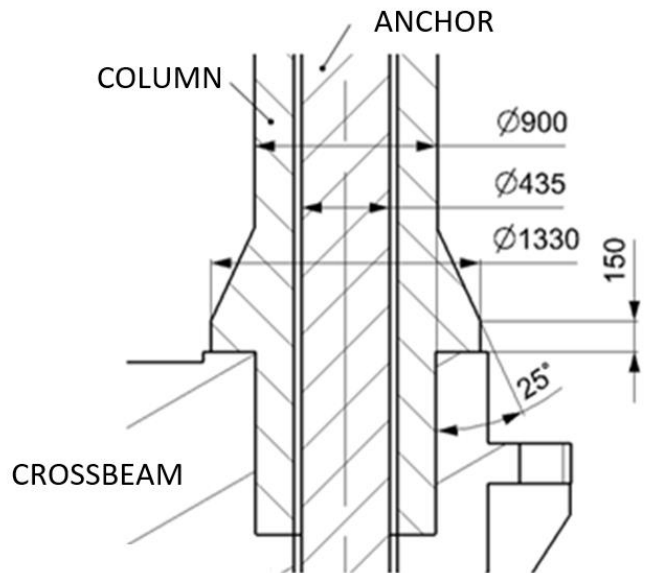


Figure 7. Collar drawing

- Oscillations of anchors: 14.151; 14.250 Hz
- The lowest frequency of press: 2.350 Hz, modal bending follows at 6.274 Hz
- Type of modal shapes is the same, comparing with previous simulation. Changed are only frequency values.

Possibilities with preload change

Change of anchors preloading is next possibility (with still same dimensions of all parts). Initial stress is changed by this in columns and anchors. Results are described in following text. Main influence is only on anchors behaviour.

3.3 Initial design with preload force +10%

- Oscillations of anchors: 14.326; 14.429 Hz
- The lowest frequency of press: 2.166 Hz, modal bending follows at 5.837 Hz
- Type of modal shapes is the same, comparing with previous simulation. Changed are only frequency values.

3.4 Initial design with preload force -10%

- Oscillations of anchors: 13.935; 14.030 Hz
- The lowest frequency of press: 2.161 Hz, modal bending follows at 5.836 Hz
- Type of modal shapes is the same, comparing with previous simulation. Changed are only frequency values.

Summary of performed simulations is visible from Tab. 1.

Table 1. Modal frequency values for selected variants

Variant	Frequency [Hz]		
	Anchors oscillation		Lowest frequency of press
Initial design	14.132	14.231	2.164
Design with collar	14.151	14.250	2.350
Initial design +10% preload	14.326	14.429	2.166
Initial design -10% preload	13.935	14.030	2.161

4 MODAL ANALYSIS SIMULATIONS WITHOUT CONSIDERING CONNECTION TO BASEMENT

Modal shapes were investigated during following simulations without considering connection to the basement. It means that boundary condition of fixing is here neglected. This results and paragraphs are added just for clear understanding of boundary condition importance.

Results of modal analysis without considering fixing constraint are different as is obvious from following results (Fig. 8 and 9). Vibrations occur at higher frequencies. Vibration of anchors is not changed during this simulation. It is clearly to see from this simulation, that correct definition of boundary conditions has key role for good results and their interpretation.

Only results of initial design are shown for understating this phenomenon.

- Oscillations of anchors: 14.104; 14.310 Hz
- Lowest frequency of press: 9.950 Hz

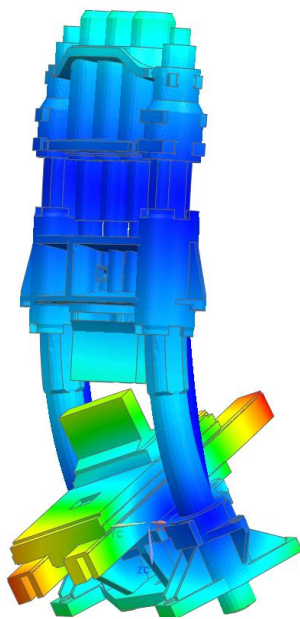


Figure 8. First modal shape of press without considering rigid fixing to the basement

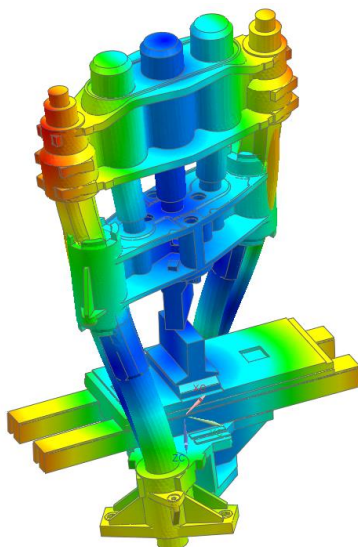


Figure 9. Second modal shape of press without considering rigid fixing to the basement

Results shows, that influence of boundary conditions is visible mainly on second shape. Value of frequency is not only one

changed result. Modal shape is changed from bending to twisting. First modal shape same is bending in direction of forging table in all simulations.

Reason, why twisting occur in this simulation, is in neglecting of lower crossbeam fixing. This kind of boundary condition is limiting movement. It leads to change of second modal shape from bending to twisting.

5 CONSLUSION

Our research shows possibilities how can be improved dynamical properties of structure (hydraulic press):

- Suitable geometrical optimization
- Change of preloading

Connection of collars to the geometry of columns has significant influence on dynamical properties. The lowest modal frequency can be increased by 10% by this simple modification. It means that frequency of forging can be by 10% higher.

Change of preload doesn't have significant influence on modal frequencies. Only anchors are affected by this change.

Correct definition of boundary conditions is one of most important points mentioned here. It is significantly effecting results from CAE simulations. It is interesting that influence on anchors is minimal (because their connection is not affected by this). Modal shapes of whole hydraulic press are highly dependent on used boundary conditions. It is obvious from different results described in this paper. Effect is in range from 2.161 up to 9.95 Hz.

Real modal frequency of this hydraulic press will be between 3 and 5 Hz according our research among users of these machines. Hydraulic presses are working with generally with lower frequencies.

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