Development and design of new mechanical forging presses

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Abstract. This article deals with the design of a new crank forging press.Forging press has to respond to higher number of customer requirements. Most of them can be divided into two categories – technological requirements and economic requirements. Technological requirements include forging of new materials which are less formable and forging of larger parts. Economic requirements are focused on dimension stability and the minimizing of the additional machining. The design of new machine must respond adequately to all requirements. Some requirements are in conflict. Several design changes are presented in the article. These changes are analyzed and their benefits described. Main design changes are focused on workspace, bearings and cranks. Virtual simulation of behaviour during forging process was used for the evaluation.

1. Introduction
Forgings are changed according demands of the industry. The key role has automotive industry. It is a dynamically changed area and therefore is necessary to improve forging processes and machines. Forging machines have a design without any significant changes for many years. Development of a new forging machine is much longer comparing to other industrial areas. Changes in design of forging machines are focused on the precision, the size of workspace and the accessibility (for manipulators). There is demand for bigger workspaces which is suitable for bigger forgings. They can be also used for the placing of the higher number of forging tools. The usage of manipulators (automation) leads to the economic benefit, reduction of production time and to the elimination of human work in the dangerous working environment.

The approach to the design of the forging press is described on three examples. Individual changes are analysed by usage of the FEM method.

2. Design changes of machines
Changes described in this paper are describing the machine with the bigger workspace. Widening of the machine was the first change of the existing forging press. Duplication of connection rods was the second design change. Adding of the central bearing was necessary for the sufficient stiffness of the press. Each design change is described deeply and all effects are shown. The validation is performed by virtual simulation [1, 2].

2.1. Workspace
The widening of the bed allows usage of the higher number of forging tools. The accessibility of workspace is also improved by this design change. The initial width of workspace was 1740 mm and it can be extended up to 2740 mm. The disadvantage of this change is decreasing of the guidance...
stability and bigger tilting of the ram during eccentric forging. The crankshaft is longer and the bending effect is higher comparing to the initial design with shorter crankshaft [3, 4].

2.2. Duplication of connecting rod
It is necessary to ensure the stability of forging ram during eccentric forging. Usage of two connecting rods is the way how to do that. This solution can have problem with a stroke instability of ram because of crankshaft twisting. The reduction of guidance loading and better accuracy are significant.

2.3. Supported bearing of crankshaft
Application of third bearing the middle of the crankshaft allows usage of two connecting rods. This bearing is reducing bending of crankshaft and total displacement. The torsion of the crankshaft is not affected by this change [5].

3. Analysis of design changes
Design changes are applied on various forging presses with nominal forging force 25 MN. Each machine had different dimensions of workspace. The frame of presses is welded and preloaded. The crankshaft is oriented from the left to the right side of machine. Three various designs of press were developed with widths 1240, 1740 and 2240 mm. Two bigger machines have two connecting rods. It was evaluated also how dimension between connecting rods is effecting the behaviour of machine. This was performed only for the biggest machine. All machines were loaded by centric and eccentric force. Distance of the eccentric load from the middle of machine was changed from 300 mm to 550 mm and 800 mm (with respect to size of machine). The design of machine with width of workspace 2240 mm is nowadays nowhere produced. It is used here as an example of possible design development. Two various designs are shown in figure 1 [6, 7].

Following parameters were used for comparing of each designs:
- loading of the crankshaft,
- vertical displacement of the ram,
- tilting of the ram during the eccentric forging,
- forces acting to the guidance during the eccentric forging.

![Figure 1. Forging press with one connecting rod (left) and two connecting rods (right).](image-url)
3.1. Boundary conditions
The constraint (fix), loading, friction and clearance in contacts are same for all compared designs. The machine is fixed on lower surfaces of preloaded anchors. The loading force is 25 MN and it is applied on the surface where are placed forging tools. This force is moved by eccentricity value during eccentric loading. The torsion of crankshaft is not considered because it is same for all solutions. It possible to see boundary conditions and various clearances in simulation model in figure 2.

![Boundary conditions and clearance in contacts](image1)

**Figure 2.** Boundary conditions (left) and clearance (mm) in contacts (right).

3.2. Results from virtual simulations
Points for tilting analysis of the ram are shown in following figure 3.

![Measurement points and displacement during forging](image2)

**Figure 3.** Measurement points (left) and maximal displacement (mm) during centric forging (right).
The value from the middle of the ram is used during centric loading. Values from side corners are used during the eccentric loading. These values are used for the calculation of the tilting angle. The force acting to the guidance’s surface is used here. Displacement during centric loading is shown on the right side in figure 3.

4. Analysis of results
All results from virtual simulations are shown in following table 1. It is obvious to see effect of machine dimensions on stress and deformation.

| Width of table/eccentricity (mm) | 1240/300 | 1740/550 | 2240/800 | 2240/800 |
|----------------------------------|----------|----------|----------|----------|
| Connecting rod- stress (MPa)     |          |          |          |          |
| without bearing                  |          |          |          |          |
| centric                          | 140      | 170      | 150      | 180      |
| eccentric                        | 170      | 230      | 210      | 260      |
| with bearing                      |          |          |          |          |
| centric                          | -        | 130      | 110      | 110      |
| eccentric                        | -        | 220      | 200      | 200      |
| Displacement of the ram (mm)     |          |          |          |          |
| without bearing                  |          |          |          |          |
| centric                          | 1.8      | 3.2      | 4.3      | 5.4      |
| eccentric                        | 1.1–2.5  | 1.3–3.5  | 1.2–4.4  | 1.8–6.1  |
| (0.06°)                          | (0.07°)  | (0.08°)  | (0.11°)  |          |
| with bearing                      |          |          |          |          |
| centric                          | –        | 2.9      | 3.9      | 4.6      |
| eccentric                        | –        | 0.8–3.3  | 0.7–3.9  | 1.2–5.1  |
| (0.08°)                          | (0.08°)  | (0.08°)  | (0.10°)  |          |
| Force acting to the guidance (MN)|          |          |          |          |
| without bearing                  |          |          |          |          |
| eccentric                        | 2.9      | 3.4      | 3.9      | 6.7      |
| with bearing                      |          |          |          |          |
| eccentric                        | -        | 2        | 2.1      | 4.3      |

4.1. Loading of crank
Loading of the connecting rod is an important parameter with respect overloading and cracks on the frame. It possible to see, that increasing of connecting rod’s loading is not so significant with respect increased width. The influence is more important during eccentric loading. Effect of the middle bearing is important during centric loading. The eccentric loading is not affected by this design change.

Decreasing of stress is notable between width 1740 mm and 2240 mm. Reason is the notch effect of the middle bearing between two rigid eccentric surfaces. It is possible to see this effect in the following figure. The middle bearing is not effecting strength of connecting rod significantly because of necessity of considering eccentric loading. It is important to have maximal distance between two connecting rods.
4.2. Displacement of ram
The displacement of ram during eccentric loading can be considered as stiffness of individual design. Bigger width leads to the lower stiffness. The benefit of the middle bearing is more significant for wider design of machine. Influence of middle bearing and higher distance between connecting rods is beneficial for eccentric loading.

4.3. Forces in guidance
Forces are acting into the guidance during eccentric loading only. They are acting also during centric loading, but they are negligible. Eccentric loading is increased with a higher eccentricity. Part of this load is transferred into the drive and the guidance. The middle bearing has positive influence on behaviour of the press. Minimal distance between two eccentric surfaces of crankshaft has negative influence. This minimal distance can increase loading twice. Higher deformations are caused by upper crossbeam (which is not sufficiently rigid) and by deformations of the crankshaft.

5. Conclusion
Main advantages and disadvantages were described for all designs above. The wider machine has higher deformation comparing to initial one. Displacement between both sides of the guidance (simulation without contact in guidance) was 1.1 mm. This value is causing significant friction losses and it can result in to the machine jam. This problem can be solved by higher clearance in guidance but it is reducing accuracy of machine. It is possible to recommend all design changes after inspection of results which was performed. It is beneficial to use two connecting rods with minimal distance between them. There should be middle bearing which is increasing stiffness of the forging press.

Mechanical forging press with parameters, which are described in this paper has better properties comparing to regular press with one connecting rod and without additional bearing. It is necessary to ensure stiffness of guidance without possibility of machine jam. Problems with stopping of ram movement will be described more deeply in following research.

6. References
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