Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 100 (2015) 891 – 898

Procedia Engineering

www.elsevier.com/locate/procedia

25th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM 2014

Options of Advanced Simulations of Crank Presses Loading

Martin Zahálka*, Jiří Staněk

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

Abstract

This paper deals with the possibilities of advanced FEM simulations used for the understanding of process of loading of crank presses. Concrete example presents transient (time-dependent) dynamic simulation loading. Load input parameters of forging press are determined from simulation of technological operation of forming. Results of virtual simulations are compared with standard analytical calculations.

Peer-review under responsibility of DAAAM International Vienna

Keywords: forming machine; crank press; FEM analysis

1. Introduction

The developing possibilities of computer equipment and software bring new simulation procedures for determining of the forging machines loading. Although the current level of the FEM calculations seems to be sufficient, it is necessary to monitor the developments, which can help us. Therefore, the CVTS (Research Centre of the Forming Machines Design) at UWB in Pilsen (www.cvts.zcu.cz) deals with the problems of machine design and simulation.

We use the static calculations that do not include the time. These calculations considering one position of the mechanism of the machine where it is usually applied the load of nominal power. We present new kinds of calculations, where we focused on the analysis of dynamic, time-dependent behavior of forming machines and also the possibility of linking together the various kinds of virtual simulations in this article.

In this example, the starting point is chosen simulation of forging technology [4] (drop forging) suitable for crank

* Corresponding author. Tel.: +420-377-638-254.
E-mail address: martinza@kks.zcu.cz

Peer-review under responsibility of DAAAM International Vienna
doi:10.1016/j.proeng.2015.01.446

press with force of 16 MN [2]. Outputs of forging simulation are further put into dynamic simulation of crank press. Monitored parameter is the torque on the crankshaft, which is required for applying workforce. The obtained simulation results are then compared with classical analytical calculations.

2. Simulation parameters

2.1. Crank press 16 MN

For the simulation was chosen crank press with a nominal power of 16 MN (1,600 t) with eccentric shaft mounted front to back. It is a single point press designed for transfer die forging.

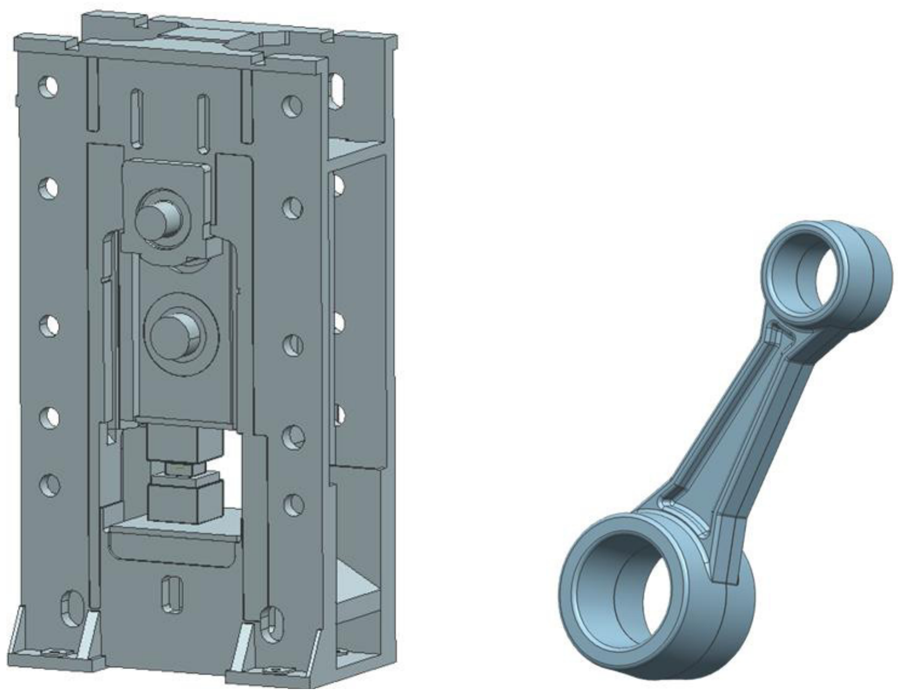


Fig. 1. (a) Crank press with nominal power of 16 MN; (b) Conrod – final shape.

2.2. Forging operation

The selected technological operations is hot die forging. The forging is semi-finished product of conrod, which is in similar forging machines usually produced [1].

Due to balanced distribution of forces along the die, semi-finished products are forged in a pair other rotated by 180°.

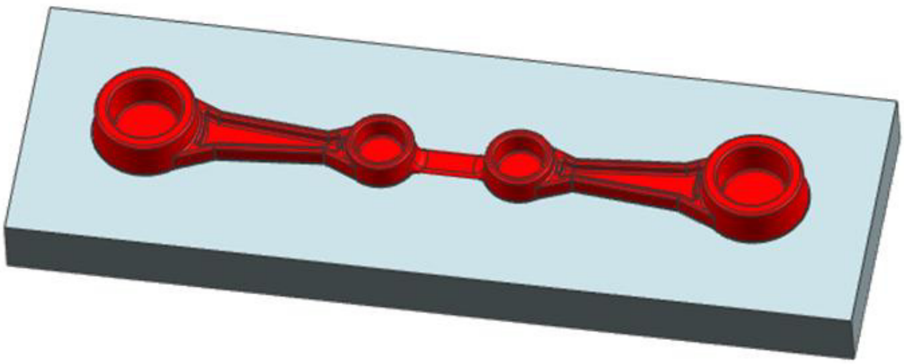


Fig. 2. Conrod in a pair.

2.3. Forging simulation

Simulation of forming was performed to obtain the course of forming power [7], which is used as the loading in the simulation of the crank press working.

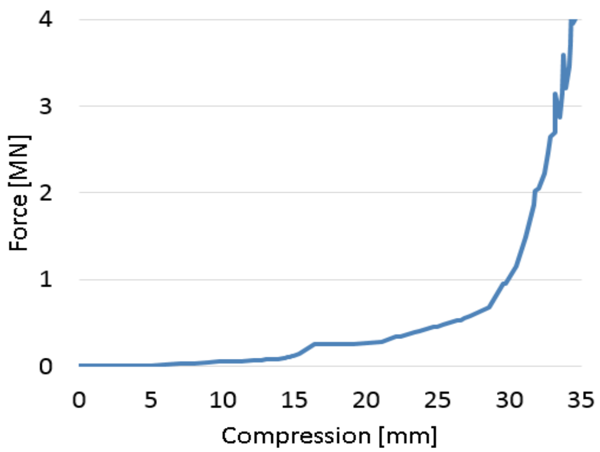
Simulation parameters:

- Material DIN 12 060 (AISI 1055)
- Temperature 1100 ° C
- Weight 8 kg

The maximum force of 4 MN was reached during the compression of the material of 34.5 mm. The simulation was performed for ¼ model, therefore a force of 4 MN corresponds to ¼ part of semi-finished product. For the whole part is a force of 16 MN.

The course of forming forces measured from simulation was simply replaced by a pair of linear curves. Thïs simplified the force is still used for both analytical load calculation and simulation load. These curves can be defined by the end points of which are:

- Compression of workpiece - 0 mm Force - 0 MN
- Compression of workpiece - 29 mm Force - 2.8 MN
- Compression of workpiece - 34.5 mm Force - 16 MN



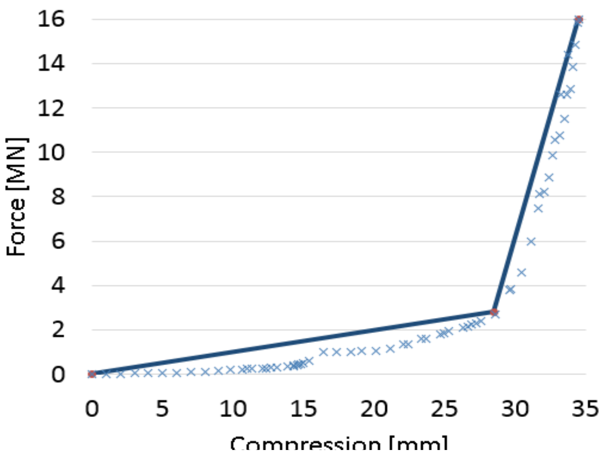


Fig. 3. (a) The course of forming forces (forming characteristics) measured by Deform 3D; (b) Replacement forming characteristics by two lines.

3. Standard analytical calculation

3.1. Nominal power at nominal angle

Standard analytical calculation based on the mechanics of the crank mechanism assumes situation where the nominal force is reached when the crankshaft is in the nominal angle before lower dead point [4]. For the purpose of calculating the basic parameters are specified:

- Nominal force Fj = 16 MN
- Nominal angle αj = 15 °
- Lift h = 370 mm

and other (conrod length, shaft diameter, coefficient of friction, ...)

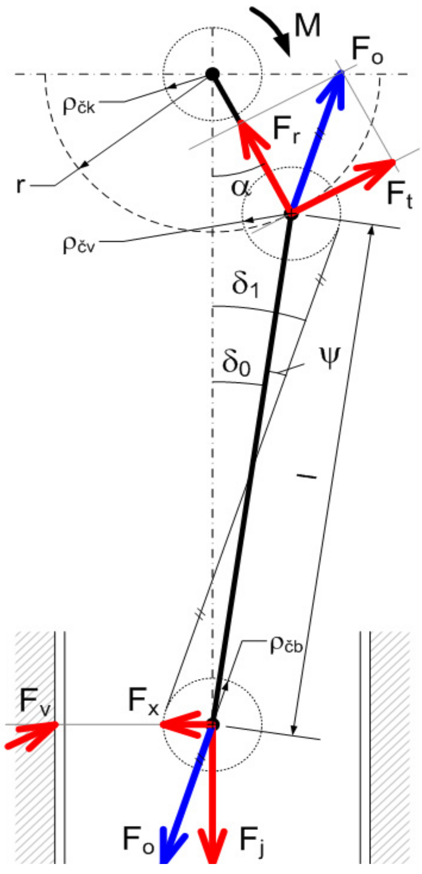


Fig. 4. Force decomposition of the crank mechanism.

The search result is required driving torque of the crankshaft, which consists of torque necessary to rotate the crank mechanism and the torque necessary to overcome the friction. The resulting value of the total torque is:

$$M_c = 1{,}2 \text{ MNm} \tag{1}$$

3.2. Variable force

By improving previous calculation of concrete course of forming force during stroke of the press can be actual torque computed by the analytical calculation. The calculation is performed according to the same relationship as the previous calculation (nominal power at nominal angle) with the difference that is made for a lot of steps (in our case, is used MS Excel). Since the deformation of the working area of the machine is not considered in the calculation, the compression of material is directly transferred to the stock stroke crank mechanism. The friction forces of the ram are not considered in the calculation.

The following figure shows the courses of moments depending on the stroke of the ram before lower dead center.

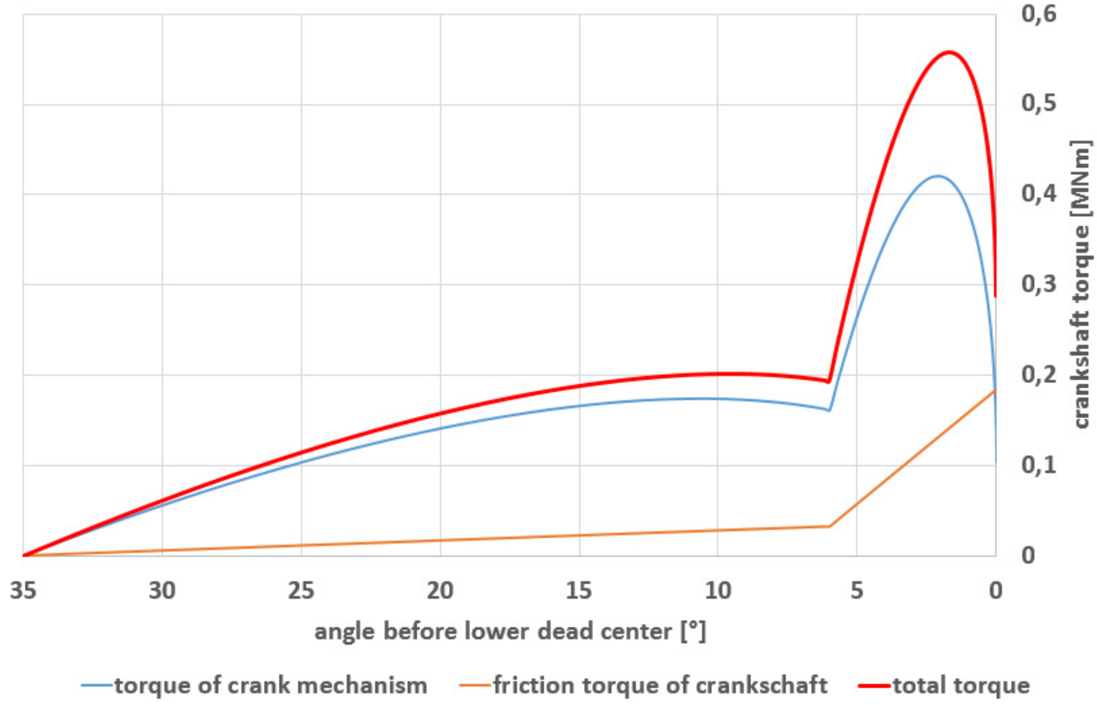


Fig. 5. Dependence moments and angle before lower dead center.

Maximum torque of 0.57 MNm is reached 7 ° before lower dead center. Comparing of the results with the torque value obtained in the previous case is evident difference. This is due to the different machine load description.

4. Virtual simulation of the press loading

4.1. Model loading – implementation of forming characteristics

Virtual simulation is performed for multi-body model. All bodies are connected with real contacts including friction [6]. The forming force is simplified to a linear course as shown in Fig. 5. The analysis is performed with consideration of gravity and dynamic forces.

Because forming force based on compression of the material between the anvil, in this simulation is inserted a piece of compressible material between the anvil also. The material must be chosen and distributed so that the compression create resistance (force) corresponding to the forming characteristic and represents the real material. The stiffness of the compressed material can be described as a spring. Because the forming characteristic is describe by two lines which represents stiffness of the material also, two unequal long, centrally located, parallel springs are used [8].

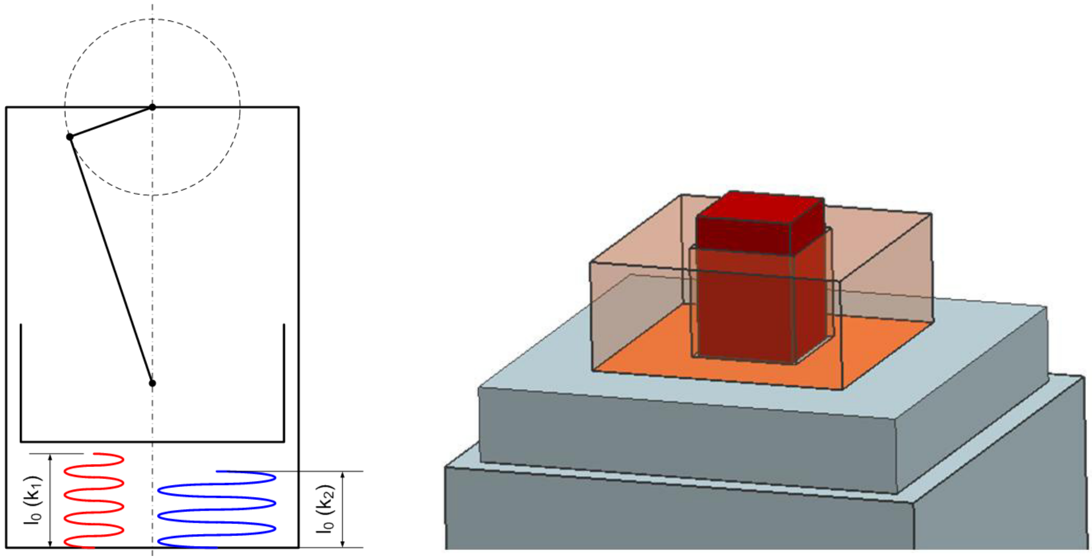


Fig. 6. (a) Inserting forming forces to the press by two springs; (b) Replacement of the forged piece by two unequal height pieces of elastic material.

Compressed metal is replaced by an isotropic material with modulus of elasticity of 3.5 GPa and Poisson's ratio of 0.33.

4.2. Motion definition

Crankshaft rotation speed is set at 1 rev. / Sec (60 rev. / Min.). Constant angular displacement is defined on the shaft in areas where there is a connection to the drive. The crank mechanism is loaded from zero angular velocity. Therefore, in the first step of calculation may results dynamic behavior of the mechanism (increase of torque due to acceleration).

Calculation, due to its complexity, not considering the whole stroke of the press, but is executed only in the area in which is material formed. In this specific case it is the angle about 40 ° before lower dead center. The calculation starts in angle of 43 ° before lower dead center and ends 12 ° over lower dead center. The calculation is set in a total time of 0.15 s. This period is divided into individual steps of 0.002 s. Total angle of rotation, which executes shaft, is 55 °.

4.3. Analysis results

The following graph (Fig. 10) shows the force on the tool (ram) measured from the simulation depending on the rotation of the crankshaft. The graph shows actual values (crosses) that are interleaved with the curve (average of two neighboring values).

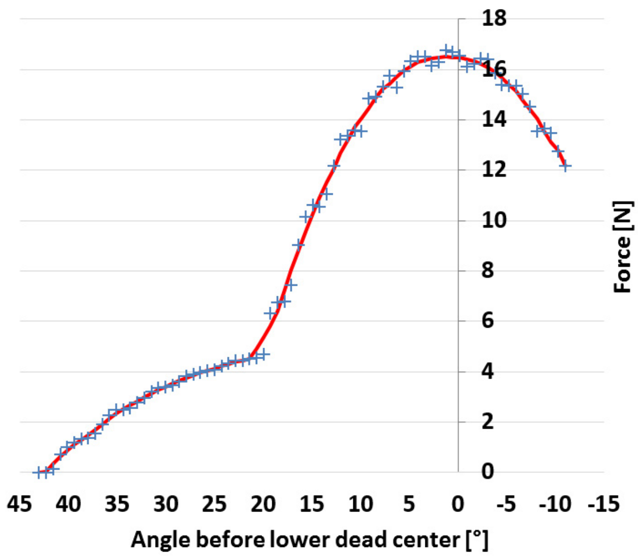


Fig. 7. The output power of the tool (ram).

The maximal load on the press is 16.8 MN (1 ° before lower dead center), which means that the desired value (16 MN) was slightly exceeded.

Shaft torque

Torque is derived from stress values at the surface of the shaft and the shaft diameter [5].

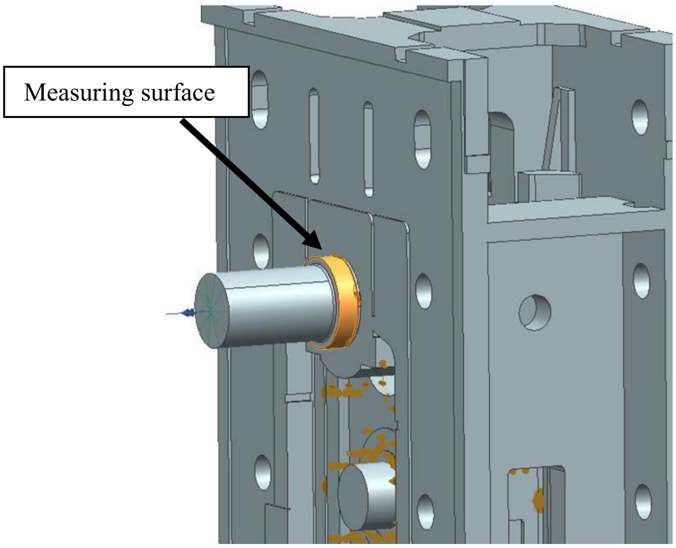


Fig. 8. Torque measuring place.

From the beginning of the torque course visible sharp increase followed by a slight decrease, which is caused by the dynamics of the crank mechanism acceleration. After stabilizing the rotation torque has continuously growing. At the bottom dead center torque decreases already (decreases torque required for forming power due to the transfer of the crank mechanism and an increased friction.

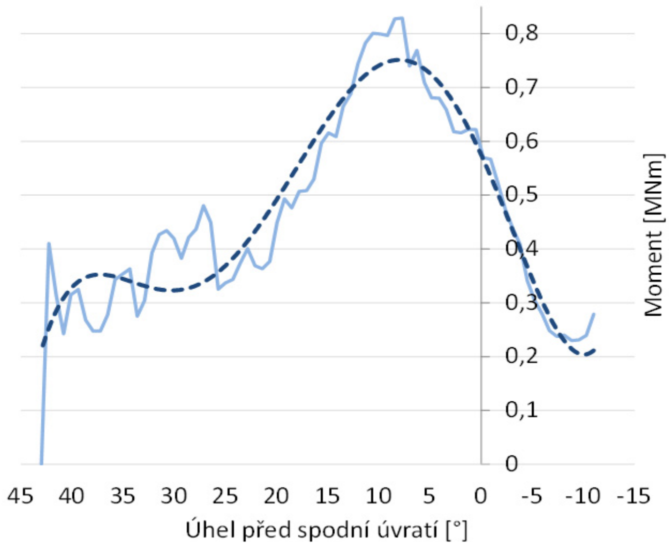


Fig. 9. Crankshaft torque.

5. Conclusion

In the paper we focused on comparing of the two types crank press calculation. One is the analytical calculation and the second is an advanced simulation of the dynamic behavior of the crank press. As comparative value is used torque of the crank mechanism shaft.

By using standard analytical calculation was found maximum torque value 0.57 MNm at 7 ° before lower dead center. The virtual simulation detected torque 0.8 MNm at 10 ° before lower dead center. Moment reached at bottom dead center is 0.18 MNm with analytical calculation and 0.5 MNm with virtual simulation.

The possibility of reaching different values can be not considering all the friction losses in the analytical calculation and not considering the elastic deformation of the machine. All these effects can negatively affect the machine kinematics.

By comparing the values obtained with the virtual simulation to the classic analytical calculations, we find that the virtual simulation exactly shows the real machine behaviour. The disadvantage of this time-dependent simulation is its requirements on computer equipment given by repeated calculation for many time steps.

This virtual simulation brings a new perspective on the interaction of technology and forming machines. The results are helpful for designers, but of course they can serve as the technologist for understanding the operation of the machine.

References

[1] M. Cechura, J. Hlavac, J. Kubec, Functions and features monitoring of forming machines, V-10-091, VSCVTT, Prague, 2010.
[2] M. Cechura, Z. Chval, Kovarenstvi. Convectional versus multiple operating press, May 2013/17, 67-70, ISSN 1213-9289, Brno, 2013.
[3] G. Dhondt, The Finite Element Method for Three-Dimensional Thermomechanical Application, John Willey& Sons, Ltd., 2004.
[4] M. Cechura, Z. Chval, Yoke mechanism for transmitting force in the forging press, Czech utility model, number 25758, 2013.
[5] J. Hlavac, M. Cechura, V. Kubec, Technologia, Boundary conditions setting questions for virtual simulation of mechanical presses, September 2009/9-10, 61, ISBN 978-80-227-3135-5, Bratislava, 2009.
[6] J. Hlavac, M. Cechura, V. Kubec, Technologia, The development of virtual simulation in design of mechanical presses, September 2011/13, 61, ISBN 978-80-227-3545-2, Bratislava, 2011.
[7] D. Banabic, Advanced Methods in Material Forming, Springer, 2007.
[8] M. Cechura, Z. Chval, Mechanism for transmitting force in the forging press, Czech utility model, number 25757, 2013.