[Volodin, 4(1): January 2017] ISSN 2348 – 8034
DOI- 10.5281/zenodo.252251 Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

STUDY OF INFLUENCE OF GEOMETRIC PARAMETERS' TOOL FOR HOT VOLUME STAMPING OF ORBICULAR IN TERMS OF FORGING ON CRANK PRESS DYNAMICS

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ABSTRACT

The magnitude of dynamic loads is one of the factors that reduce the reliability and durability of the crank hot presses, which can be controlled by selecting from a set of possible, more efficient version of the technological scheme of stamping products. In this paper the nonlinear model of the plastic deformation process forging on crank hot press designed for the calculation of indicators that determine the level of dynamic processes in the elements of the press, depending on the geometrical parameters of the tool used to form forgings, as well as the results of the design process flowsheet stamping to minimize dynamic loads in the press.

Keywords: *crank press, technological effort, stamp, dynamic model, mathematical model, pre-punching the transition, the final stamping transition.*

I. INTRODUCTION

In the foreseeable future, hot volume stamping on crank hot presses remain one of the main methods of production of forgings with high operating properties, in which the cost of the metal and the cost of equipment is the main component. The classic way to the formation of the specified size forgings - tightening parameters of flash bridge: an increase in the width and height reduction. Herewith the stamping's force increases and thus the operating conditions of the equipment worsen, especially due to the resulting oscillating (dynamic) processes in the system, combining shafts, connecting rod, crosshead and press's base frame [1, 2].

The obvious way to improve the reliability and durability of the press is the creation of new technological schemes of hot volume stamping that enable to minimize the dynamic processes in crank hot presses [3, 4] by changing the behavior of technological schedule loads and their values.

II. RESEARCH METHOD

Mathematical model of the press is a system of common, non-linear, piecewise continuous second-order differential equations describing the movement of the masses of the system connected by a kinematic and elastic-dissipative connections – dynamic model (Picture 1). In the development of a dynamic model it was assumed that the stamping on crank hot presses, maximum loads occur at the end of stroke slider, when the rotational component of the efforts from the slide on the press's main shaft is minimal.

At this time warp elements of the press: frame, connecting rod and slide experience predominantly stress-strain deformation, and the main shaft running on a bend. During the rest of the time the load circuit of the main shaft - torsional and flexural strength. At this time press elements: frame, connecting rod and slide experience predominantly stress-strain deformation, and the main shaft runs on a bend. During the rest of the time the load scheme of the main shaft - torsional and twist.

ISSN 2348 – 8034
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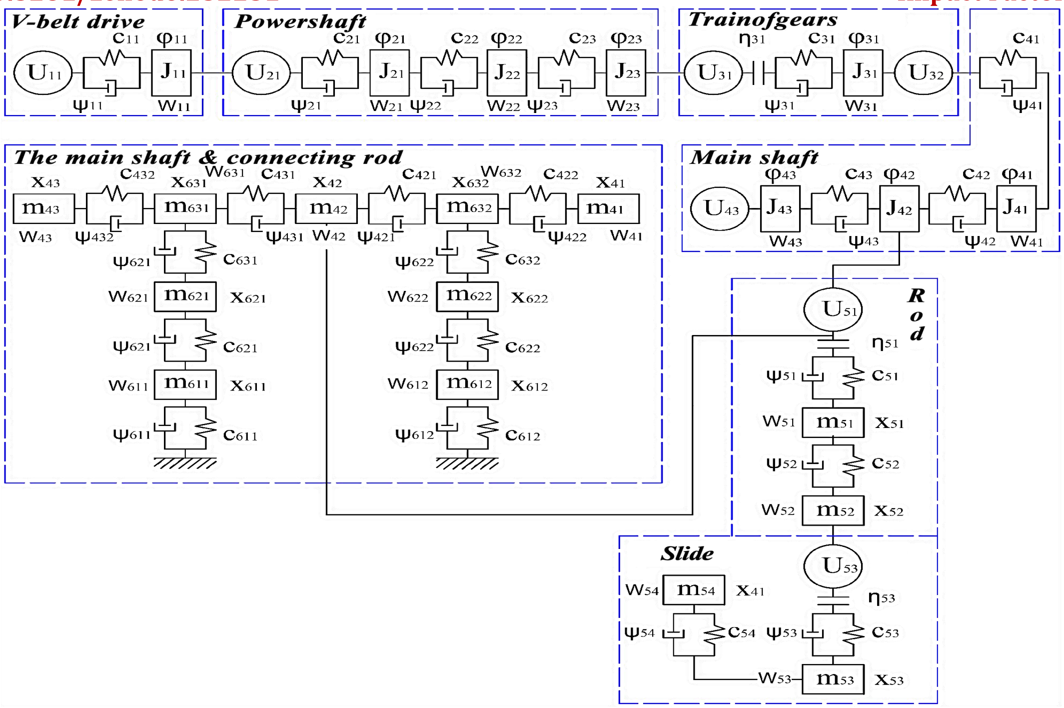

Picture 1. A dynamic model of the crank hot stamping presses

Jij – inertia moment, mij – mass, cij – rigidity, ψij – dissipation coefficient, ηi – gap, Uij – position function, Wij – external load j mass of the i mechanism

The method of constructing a mathematical model is based on the use of the equation La grange of second kind, for example, for the slider-crank mechanism of the equations of motion of its mass (Picture 1) can be written as:

$$\begin{cases} m_{51}\ddot{x}_{51} = -c_{51}(x_{51}-U_{51}) - b_{51}(\dot{x}_{51}-U'_{51}\cdot\dot{\varphi}_{42}) + \Omega_{56} \\ \qquad + c_{52}(x_{52}-x_{51}) - b_{52}(\dot{x}_{52}-\dot{x}_{51}) + W_{51} \\ m_{52}\ddot{x}_{52} = -c_{52}(x_{52}-x_{51}) - b_{52}(\dot{x}_{51}-\dot{x}_{51}) + \\ \qquad + c_{53}(x_{53}-U_{53}) - b_{53}(\dot{x}_{53}-U'_{53}\cdot\dot{x}_{52}) + W_{52} \\ m_{53}\ddot{x}_{53} = -c_{53}(x_{53}-U_{53}) - b_{53}(\dot{x}_{53}-U'_{53}\cdot\dot{x}_{52}) + \\ \qquad + c_{54}(x_{54}-x_{53}) - b_{54}(\dot{x}_{54}-\dot{x}_{53}) + W_{53} \\ m_{54}\ddot{x}_{54} = -c_{54}(x_{54}-x_{53}) - b_{54}(\dot{x}_{54}-\dot{x}_{53}) + W_{54} \end{cases}, \quad (1)$$

$$\Omega_{45} = c_{51}(x_{51}-U_{51}) + b_{51}(\dot{x}_{51}-U'_{51}\cdot\dot{\varphi}_{42})$$
$$\Omega_{56} = c_{51}(x_{42}-x_{51}+U_{51}) + b_{51}(\dot{x}_{42}-\dot{x}_{51}+U'_{51}\cdot\dot{\varphi}_{42}), \quad (2)$$

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$$U_{51} = R\cdot(1-\cos(\varphi_{42}) + L - \sqrt{L^2 - 2R\cdot\sin(\varphi_{42})},$$

$$U'_{51} = R\cdot\sin(\varphi_{42})\cdot\left(1+\frac{R}{\sqrt{L^2-2R\cdot\sin(\varphi_{42})}}\right),$$

$$U_{53} = x_{52},\ U'_{53} = 1, \quad (3)$$

In equations (1 – 3) $x_{5n}, \dot{x}_{5n}, \ddot{x}_{5n}$ – linear displacement, velocity and acceleration of the masses of slider-crank mechanism, (n = 1 … 4); m_{5n}, c_{5n}, b_{5n} – mass and elastic-dissipative characteristics of the model, W5n – external loads: the friction force, balance slider, technological capacity; Ω_{45} – the impact of the rod press on its main shaft, Ω_{56} – the impact of frame system – the main shaft on the connecting rod, R and L – radius and length of the rod respectively.

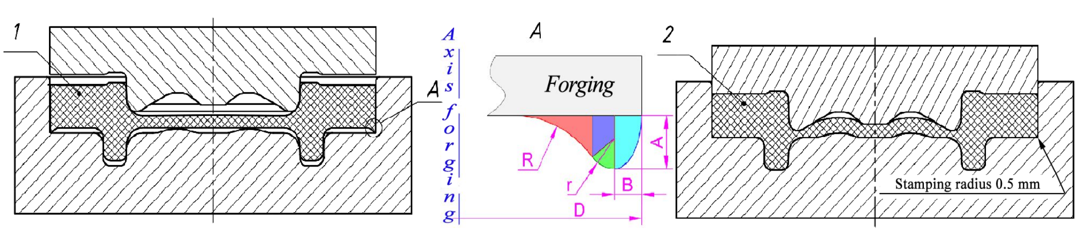
To assess the level of dynamic processes in the slider-crank mechanism of the press such criteria (4) will be used:

$$K_s = \frac{P_{ЯП}}{Ps_{ЯП}},\quad K_m = \frac{P_{\max}}{Ps_{\max}}, \quad (4)$$

where Pcp, Pscp, Pmax и Psmax – respectively, the average dynamic, static medium, dynamic and static load maximum on absolute value in the examined mechanism element, calculated on [T1, T2] time interval. Km coefficient determines the relative level of the maximum load in the studied mechanism of the press and is an indication of strength. Ks value depends on the amplitude, frequency, speed of oscillation fading and is a factor determining the wear and fatigue damage. The values of the average and maximum dynamic loads, for example in the connecting rod press can be found by solving the equations of motion according to dependences (5):

$$P_{ЯП} = \frac{1}{T_2 - T_1}\int_{T_1}^{T_2} \left|c_{51}(x_{51}-U_{51})\right|\cdot dt,\quad P_{\max} = \max\left|c_{51}(x_{51}-U_{51})\right|_{T_1}^{T_2}. \quad (5)$$

One of the modern trends of design of hot value stamping processes is the formation of the process projections in the preliminary transition, which allow to get the forging to a minimum stamping radius at lower stamping effort and thereby reduce the machining allowance (Picture 2).



Picture 2. Stampings of orbicular in terms of forgings (final transfer):

1 - semi-finished product formed during the pre-transition 2 - finished forging

Mathematical model (6, 7), sets configuration projection (Picture 2) in the coordinates y(x):

$$y = \begin{cases} -\frac{A}{B}\cdot\sqrt{\left|(x-0.5\cdot D+B)^2-B^2\right|} & 0 \le x-0.5\cdot D+B \le B \\ r-A-\sqrt{\left|(x-0.5\cdot D+B)^2-r^2\right|} & -r\cdot\sin\alpha \le x-0.5\cdot D+B \le 0 \\ -R+\sqrt{\left|(x+(r+R)\cdot\sin\alpha-0.5\cdot D+B)^2-R^2\right|} & \begin{cases} x-0.5\cdot D+B \le -r\cdot\sin\alpha \\ x-0.5\cdot D+B \ge -(r+R)\cdot\sin\alpha \end{cases} \end{cases} \quad (6)$$

$$\alpha = \arccos\left(\frac{R-A+r}{r+R}\right)$$

In equations (6) the angle is in radians

$$\begin{cases} \overline{\alpha} = 90 - \frac{180\cdot\alpha}{\pi}; \quad 20^\circ \le \overline{\alpha} < 90^\circ \\ 0.6 \le \frac{4\cdot A^2}{\pi\cdot A\cdot B + 2\cdot(r^2-R^2)\cdot\alpha + 4\cdot(A-r)\cdot(r+R)\cdot\sin\alpha + (r+R)^2\cdot\sin 2\alpha} \le 1.2 \end{cases}$$

(7)

Expression (7) defines the conditions of defect-free stamping in the final transitions of half-stuff with a projection obtained in the pre-transition.

III. RESULTS & ANALYSIS

In the study of the influence of geometric parameters' tool for hot value forging of orbicular in terms of the dynamics of forging on dynamic of crank press the following tasks were solved:

1. Values' search of parameters A, B, R and r (Picture 2) allows to minimize maximum static stress Psmax in the final transition at the formation at the outer side of the forging of stamping radius not exceeding 0.5 mm.
2. Calculation criteria Km, Ks, Pm and Ps at obtained at values Ps A, B, R and r
3. Research of influence of changes in the values A, and R on the criteria Km and Ks . Here, taking into account the results of solving the problem №1, B = 0.5•A, r = B was made..

To calculate press's dynamic characteristics special software was used [5], which is based on dynamic (Figure 1) and Mathematical (1) - (5) models, as well as QuantorForm Ltd company's software – QForm 8 for modeling hot volume stamping and calculating technological load [2, 3].

The object of study - forging manufactured at crank hot press K8542 – nominal force of 16 MN, in accordance with the flow chart shown on the Picture 2.

Task №1 – solution with the help of the descent method under the constraints (7). The result – Psmax = 10.78 MN, Pscp =2.18 MN at A = 3.0; B = 1.5; R = 3.5; r = 1.5 [mm].

Task №2. Result - Km = 1.05, Ks = 1.27, Pm = 11.32 MN and Ps = 2.78 MN.

Task №3. The range of A and R parameters' variation– ≈10%. The results are shown in the Table 1.

Table 1. Values of Km / Ks criteria for various values of A and R parameters.

		Parameter A, MM						
		2.4	**2.6**	**2.8**	**3.0**	**3.2**	**3.4**	**3.6**
Parameter R,MM	**3.0**	1.06 / 1.27	1.06 / 1.28	1.05 / 1.26	1.06 / 1.26	1.07 / 1.27	1.06 / 1.27	1.04 / 1.27
	3.2	1.05 / 1.28	1.06 / 1.28	1.05 / 1.27	**1.05 / 1.26**	1.06 / 1.27	1.06 / 1.27	1.04 / 1.28
	3.4	1.05 / 1.28	1.04 / 1.29	1.04 / 1.28	1.06 / 1.26	**1.05 / 1.26**	1.06 / 1.28	1.06 / 1.29
	3.5	1.05 / 1.29	1.04 / 1.30	1.04 / 1.28	**1.05 / 1.27**	1.06 / 1.28	1.06 / 1.29	1.07 / 1.29
	3.6	1.05 / 1.29	1.05 / 1.30	1.04 / 1.28	1.05 / 1.28	1.06 / 1.28	1.05 / 1.29	1.07 / 1.29
	3.8	1.05 / 1.30	1.05 / 1.31	1.04 / 1.29	1.06 / 1.30	1.06 / 1.29	1.06 / 1.30	1.08 / 1.30
	4.0	1.04 / 1.30	1.06 / 1.31	1.04 / 1.29	1.06 / 1.30	1.05 / 1.29	1.06 / 1.31	1.08 / 1.32
	4.2	1.04 / 1.31	1.06 / 1.32	1.04 / 1.30	1.06 / 1.31	1.06 / 1.30	1.07 / 1.32	1.09 / 1.34

In Table 1, the value areas of A and parameters R are emitted: yellow color (upper right corner) - the emergence of stamping defects; brown (bottom left corner) - the stamping radius value of more than the set value (0.5 mm); green - values of variable parameters close to the optimum.

IV. CONCLUSION

In this paper, a mathematical model of the forging's plastic deformation process on crank hot press was framed. This model allows to estimate the level of dynamic loads in the press elements, depending on the geometrical parameters of the tool, used to form forgings. The model's operability test was implemented on the example of stamping on the hot stamping press of orbicular in terms of forgings, resulting in founding values of tool's geometrical parameters close to optimal.

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