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Research Paper

The mathematical modeling for assessing the effectiveness of hot forging extruded round in plan forgings on crank presses

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Abstract

The article presents the results of the development of a mathematical model for calculating the efficiency indices of technological schemes for hot volumetric stamping (GOSH) on crank hot-stamping presses (KGSHP) round in the forgings plan (for gear, pulley and other similar parts). Software solutions obtained on the basis of this model allow choosing from several variants of technological schemes the most effective for using it in production or further improvement.

Keywords: *Hot Stamping; Metal Consumption; Billet; Forging.*

1. Introduction

The process of manufacture of forgings of the same parts by the method of (GHOSH) can be implemented by applying several variants of technological schemes [1], [2]. The best of the options possible based on the assessment of the values of the following groups of criteria that determine the metal content of the technological process (1), (2) and the conditions of service of the press (3) to (5).

1) The coefficient precision forgings [1]:

$$K_{p} = \frac{{}_{D}M}{{}_{p}M} \le 1. \tag{1}$$

2) The utilization rate of the metal [1], [3]:

$$K_{H} = \frac{{}_{D}M}{{}_{z}M_{mid}} \le 1, \quad {}_{min}K_{H} = \frac{{}_{D}M}{{}_{z}M_{max}} \le 1. \tag{2}$$

3) The safety factors for static and dynamic efforts, minimum, and average [4]:

$$\begin{aligned} K_{ZS} &= \min\left(\frac{P_{al}}{P_{S}}\right), \qquad {}_{mid}K_{ZS} = \frac{1}{T}\int_{0}^{T}\left|\frac{P_{al}}{P_{S}}\right|\cdot dt, \\ K_{ZS} &= \min\left(\frac{P_{al}}{P_{D}}\right), \qquad {}_{mid}K_{ZS} = \frac{1}{T}\int_{0}^{T}\left|\frac{P_{al}}{P_{D}}\right|\cdot dt, \end{aligned} \tag{3}$$

Where P_{al}, P_S and P_D function changes the permissible static and dynamic forces (moment forces) to press the item in the time interval T.

4) The average values of the dynamic forces or moments of forces:

$${}_{mid}P_{D} = \frac{1}{T}\int_{0}^{T} c(t)\cdot\left|x(t) - U(t)\right|\cdot dt, \tag{4}$$

Where s (t) is the stiffness, x (t) and U (t) is the displacement with and without allowance for deformation of the press element.

5) The coefficient of dynamic average and maximum load

$${}_{mid}K_{D} = \left|\frac{{}_{mid}P_{D}}{{}_{mid}P_{S}}\right|, \quad {}_{\max}K_{D} = \left|\frac{{}_{\max}P_{D}}{{}_{\max}P_{S}}\right|, \tag{5}$$

Where is the average dynamic and static force (moment of force), and the maximum absolute value of dynamic and static power.

2. Calculation of metal consumption of the technological process GHOSH

1) The metal loss that occurs during execution of the operation, GOSH, the related assignment allowances and overlaps that are removed later by machining [1]. Figure 1 shows the effect of the value of outside radius of forgings for the amount of the allowance. If δ < 0 (6) then to perform the machining it is necessary to increase the value of the stock on the side surface on the value of δD or end – to-size δT.

$$\begin{aligned} &\delta = R - \sqrt{(R - P_{T})^{2} + (R\cdot\cos\alpha - R\cdot\mathrm{tg}\alpha - P_{D})^{2}}, \\ &\delta_{D} = R\cdot\cos\alpha - R\cdot\mathrm{tg}\alpha - P_{D} - \sqrt{(2\cdot R - P_{T})\cdot P_{T}}, \\ &\delta_{T} = R - P_{T} - \sqrt{R^{2} - (R\cdot\cos\alpha - R\cdot\mathrm{tg}\alpha - P_{D})^{2}}, \\ &R > P_{T}, \qquad R > P_{D}. \end{aligned} \tag{6}$$

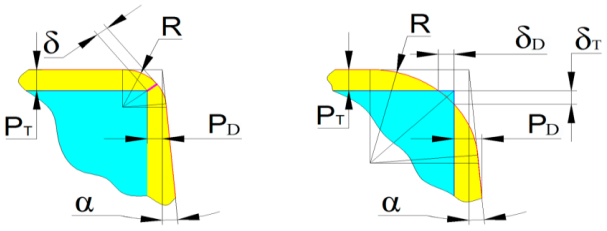


Fig. 1: To Calculate the Values of Allowances.

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In the formulas (6) R is the radius of curvature of the outer corner of the forging, α – stamping bias, RT and PD – allowances on the front and lateral surface of the cylinder, is reduced by the size of their lower minimum deviations.

Work-related assignment allowances, tolerances, overlaps in the preparation of drawing of forging is time consuming. The author proposed method of automation, which is based on the idea of spoofing the real details of the model. The model represents the Union (or subtraction) of the cylindrical surfaces. The form of the model can be described by the following expression:

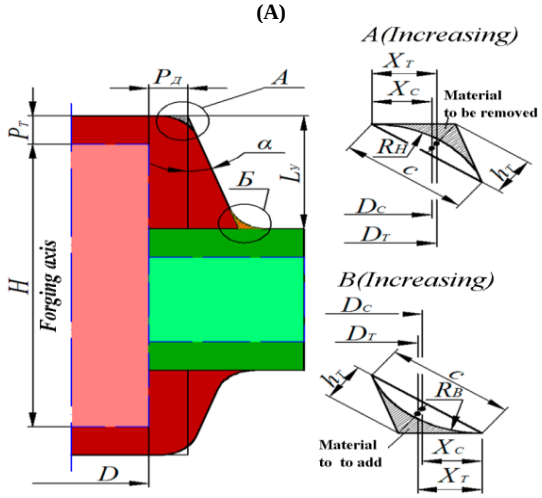
$$P(K,M,N)=\bigcup_{i=0}^{K} D_i, H_i, L_i - \sum_{m=0}^{M} \text{в}D_m, \text{в}L_m - \sum_{n=0}^{N} \text{н}D_n, \text{н}L_n \ , \qquad (7)$$

And the process of assigning allowances, tolerances and overlap to formalize (see figure 2) and program (8).

In Figure 2 overlaps a darker red and green, in comparison with the corresponding element of the model (7).

Figure 3 shows the window of a computer program where you enter the value of a data structure model of a work piece gear in accordance with the expression (7), as well as a number of key parameters required for the determination of allowances, tolerances, overlaps, and dimensions of the elements of forging and calculation of their volumes.

(A)



(B)

$$V = V_{Ц} + V_{ЦК} + V_{КК} - V_{RH} + V_{RB},$$
$$V_{Ц} = 0.25 \cdot \pi \cdot (D^2 - D_0^2) \cdot P_T,$$
$$V_{ЦК} = 0.25 \cdot \pi \cdot ((D + P_Д)^2 - D^2) \cdot L_y,$$
$$V_{КК} = 0.125 \cdot \pi \cdot ((D + P_Д + L_y \cdot tg\,\alpha)^2 - (D + P_Д)^2) \cdot L_y,$$
$$V_{RH} = \pi \cdot (D_{TH} \cdot S_T - D_{CH} \cdot S_C),$$
$$V_{RB} = \pi \cdot (D_{TB} \cdot S_T - D_{CB} \cdot S_C),$$
$$D_{TH} = A_H + X_T, \quad D_{CH} = A_H + X_C,$$
$$D_{TB} = A_B - X_T, \quad D_{CB} = A_B - X_C,$$
$$A_H = D + P_Д - 2 \cdot R_H \cdot tg\,(45 - 0.5 \cdot \alpha),$$
$$A_B = D + P_Д + L_y \cdot tg\,(\alpha) + 2 \cdot R_B \cdot tg\,(45 - 0.5 \cdot \alpha);$$

Fig. 2: Modeling Assignment Allowances and Overlaps the Outer Sides of the Elements of Forging (A) and the Expressions for Calculating Their Volumes (B).

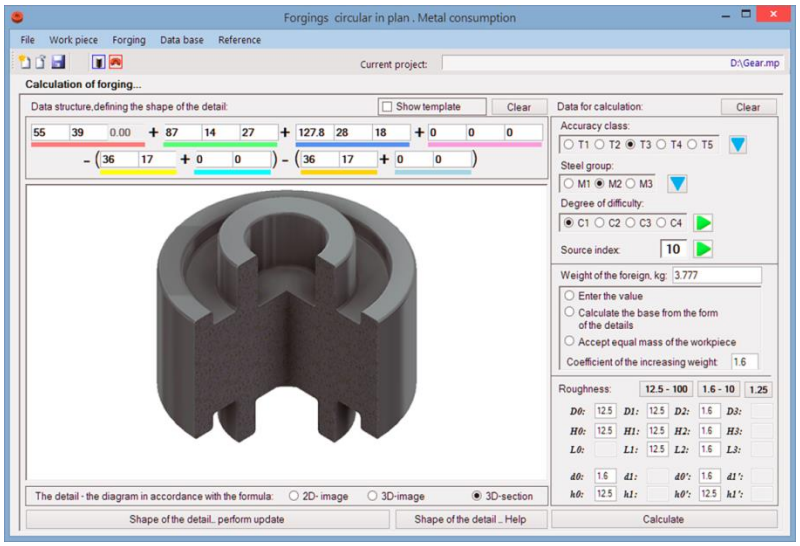


Fig. 3: The Program Window of the Input Data on the Model and the Default Values of Allowances, Tolerances, Overlaps and other Parameters Forgings.

The program window shown in figure 4 is designed to evaluate the impact of various factors on the value of the coefficient of precision forgings (1).

2) Metal loss associated with the formation of the dross.

The fin in the die forging process performs two functions:

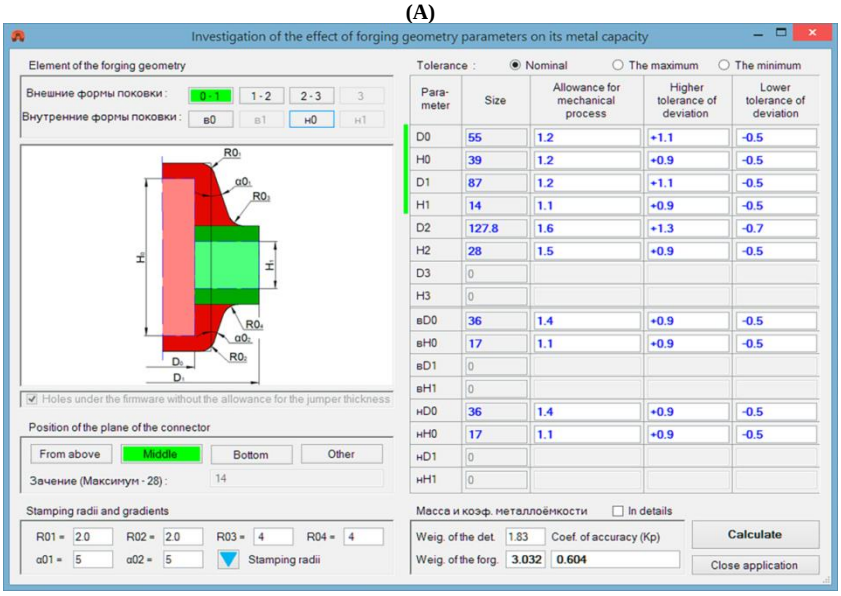
- Compensation of fluctuations in the volume of the work piece due to inaccuracies of size and scale formation.
- Change of metal flow in the direction areas of the engraving of the stamp at the end of the working stroke of the press at the final transition.

Filling the engraving of the stamp is carried out simultaneously with the formation of the dross

Figure 5 shows the results of simulation program Q Form (Kavantor form, OOO) process GHOSH on KGSP forging parts gear. This method is applicable to determine the minimum height of the work piece of a given diameter corresponding to the minimum volume.

The calculation of the coefficient of metal use and the losses associated with inaccuracies of the dimensions of the work piece, the losses when heating is considered in detail in [2]. The results of the calculations, in relation to GHOSH on KGSP forging parts gear [4], is presented in figure 6.

(A)



(B)

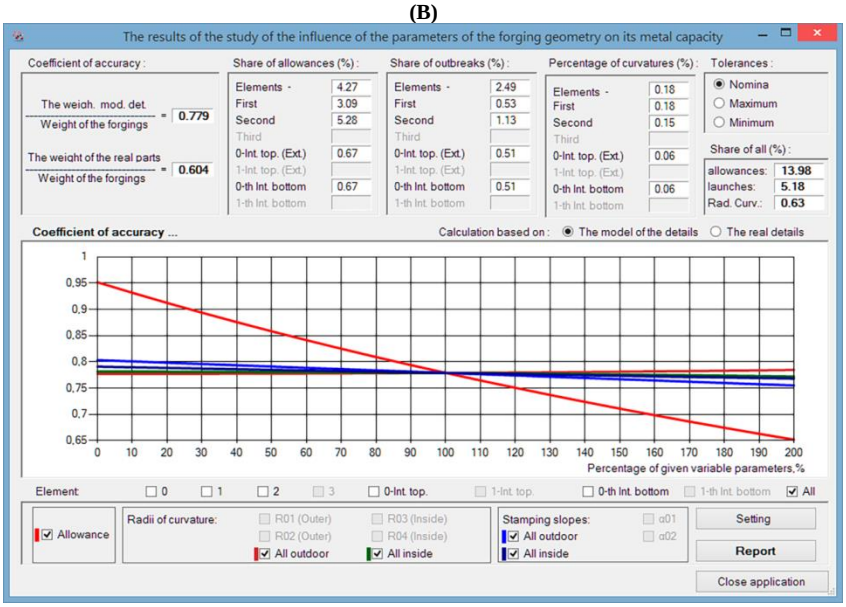


Fig. 4: A Study of the Influence of the Values of Allowances, Tolerances, Overlaps on the Value of the Coefficient of Precision Forgings In General (A) and Separately for Each of the Forms (B) Forming A Forging.

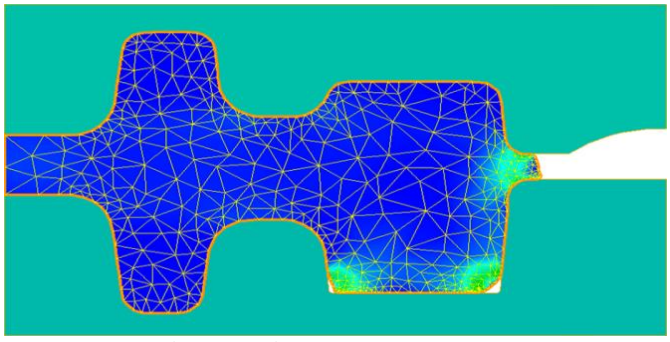


Fig. 5: The Process of Forming of the Forging at the Final Forging the Transition.

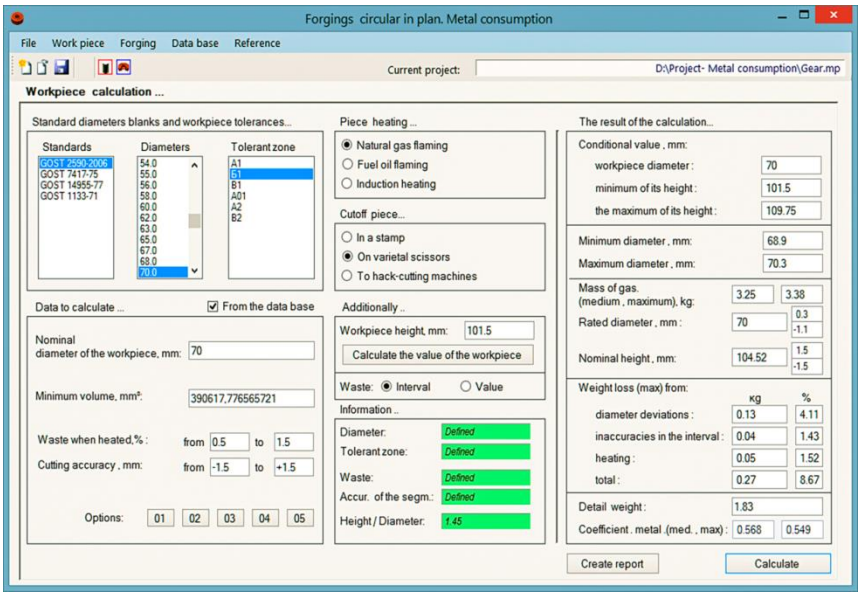


Fig. 6: The Study of Metal Process GOSH Forging Parts Gear and Calculate the Utilization Rate of Metal.

3. Assessment of working conditions KGSP when performing GOSH

Technological force punching. Reasonably accurate values can be obtained by the use of this software to simulate the process of GOSH by the finite element method (FEM), for example, Q Form. Technological effort is the most important (along with metal content) as a criterion of efficiency of technological process. Since force is a function of time or of displacement of the slider (or main shaft), for quantitative evaluation we use the factors of safety for static KGSP (GLC, SKZS) and dynamic (GLC, SKZS) forces when performing technological operations (3).

Given that currently the cost of hot-stamping presses large and proportional to the nominal stress, the GAUCHE – KGSP can be considered more effective than the value of the barrier is closer to one (GLC → 1), and crcss less (srcss → min).

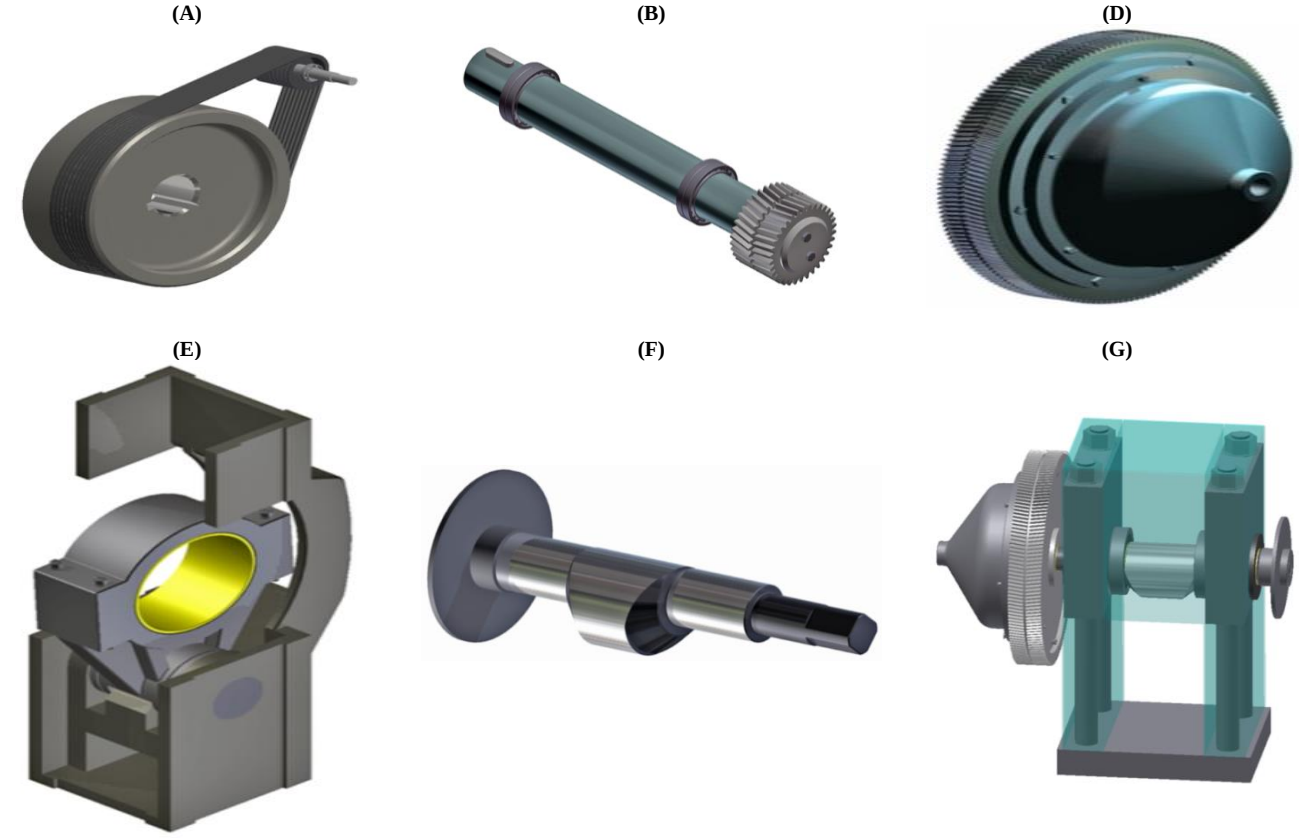


Fig. 7: Elements of Dynamic Models of the Press. (A) - Transmission V-Belt, (B) – Drive Shaft, (C) – Gear with Clutch, (D) – Rod and the Slider, € – Shaft, Main, (F) – Frame With the Main Shaft, Gear Wheel and Clutch

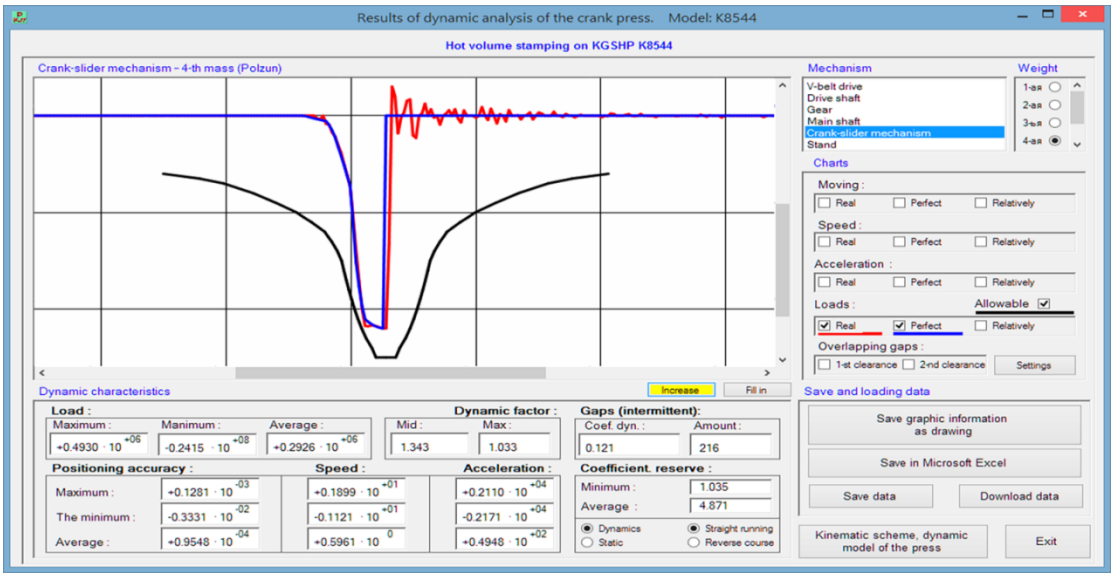


Fig. 7: Modeling of Dynamic Processes in KGSP.

The overall level of dynamic processes in the elements of the press [4], [5], [6] can be estimated by the average values of dynamic forces (4) and dynamic factors (5).

To calculate indicators (3) – (5) determining the level of dynamic processes use complex model KGSP [4], allowing to take into account the inertial, elastic, dissipative characteristics of the press parts, the clearances in kinematic pairs structural forces (trim slide) and friction. Feature of this model QGSP is the possibility of accounting as torsional deformations of the main shaft, and deformations due to its bending. The components of the dynamic model (mechanisms CGSP), shown in figure 7. Figure 8 shows the results window of the simulation of the dynamics of CGSP and calculation of several performance indicators, which is determined by the dependency (3) – (5).

4. Conclusion

This article addresses the problem of developing a mathematical model that allows calculating the performance indicators different production versions of the round in terms of forgings parts with hot forging method for a crank press. Feature of this model is the ability of the study based on it at the same time the process of forming forgings, rod manufacturers and dynamic processes in a crank press. Programs designed to address these three of the above tasks, significantly increase productivity and improve the quality of work associated with the design of technology.

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