Development of the Technology of Large Bodies Manufacturing Based on Combined Process of Plate Rolling and Stamping

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Abstract. An experimental study of the developed new technologies for obtaining large-sized parts with an elliptical surface has been carried out. The advantages and disadvantages are established, as well as the boundaries of effective applicability of new combined process. Verification of the results of computer simulation based on testing the technology in the conditions of a laboratory rolling mill was performed. Optimal geometric shapes of matrices and punches to produce spherical and elliptical bottoms of various thicknesses and diameters are obtained on a thick plate rolling mill. The methods of correction of the technology for obtaining large-sized parts with an elliptical surface have been developed and tested in laboratory conditions to eliminate the identified shortcomings.

1. Introduction
To produce large-sized (4 ... 100 mm) complex profile details with specified curvature, a new combined thick-plate rolling and stamping process has been developed. It is based on the principle of a package rolling consisting of the upper (punch), the lower (matrix) bases and a thick plate between them. The production of long-dimensioned large bodies of specified curvature on a thick plate rolling mill opens the prospect of obtaining, for example, such products as casings of various large objects. It makes the work relevant for machine building it allows to obtain blanks for long-dimensioned large-sized bodies of specified curvature that cannot be obtained without welding with the help of press equipment [1-3]. To achieve this goal, the following tasks were set and solved: the development of a methodology for the experimental study of combined rolling and stamping processes; mathematical modelling and analysis of metal shaping and force parameters of a new process under conditions of implementation on a laboratory mill; a comparative analysis of merits and identification of shortcomings of direct and reversible schemes for implementing a combined process for obtaining various details such as bottoms; the development of corrective technical and technological impacts to eliminate previously identified shortcomings. The work was based on mathematical modelling and experimental research of a new process [4-6].

2. Experimental study of the combined process of rolling and stamping
To implement the new combined rolling and stamping process, a package consisting of the upper punch and the lower die was produced. The punch was provided with a ring-shaped projection extending radially inwards and having a convex surface. The lower matrix was made in the form of a
ring 1.5 mm thick with an upper internal diameter of 160 mm. Between the punch and the matrix a sheet blank was placed made of lead 6 mm thick, which had a circle shape in the horizontal plane with a diameter of 183 mm (Fig. 1). The use of lead as a workpiece material makes it possible to simulate hot deformation at room temperature.

![Image 1](image1.png)

**Figure 1.** Experimental package: a) general view; b) cross section.

The combined rolling and punching process was performed in one or several passes (from 2 to 4) in a straightforward manner. The accuracy of the resulting geometry of the product was evaluated based on the results of the experiment. In total, 10 items have been obtained. The curvature of the finished products was checked by special templates. The deviation was from 10 to 2%, depending on the number of passes. The more the number of passes, the less the deviation. The form of the final product of the given shape is shown in Fig. 4.

In the experiment, the influence of various friction on the quality of the resulting geometry of the finished product has also been investigated. It is shown that the greater the coefficient of friction at the punch-workpiece contact and the matrix-workpiece, the smaller the deviation of the geometry.

![Image 2](image2.png)

**Figure 2.** Laboratory rolling mill duo 150 for the implementation of the combined process "rolling-stamping"

![Image 3](image3.png)

**Figure 3.** Experimental package consisting of the upper (punch) and the lower (matrix) bases and the sheet blank between them.
Figure 4. The obtained experimental sample: a) the part and the bottom base (matrix) of the package; b) general view of the part; c) the shape of the lower surface of the part.

3. Mathematical modeling of metal shaping and force parameters of the combined rolling and stamping process in conditions of realization on a laboratory mill duo 150

Mathematical modeling was carried out by the finite element method in the DEFORM 3D software package. The adaptation of the finite element mathematical model consisted in the scientifically justified formulation of the boundary and initial conditions of the problem being solved, as well as in the adoption of certain assumptions of the simulated process. The following boundary conditions were set: 1) the boundary surfaces of the working tool (matrix, punch, rolls); 2) the law of friction on contact with the working tool; 3) rheological model of the deformable material. As initial conditions for modeling, the following parameters were set: 1) diameters and angular speeds of rotation of working rolls; 2) the yield curve of the material (lead) of the billet (Fig. 5); 3) the temperature of the workpiece; 4) the initial dimensions of the workpiece; 5) the friction index m on contact with the tool; 6) the size and number of finite elements.

With three-dimensional modeling of the process, the following assumptions are accepted: 1) the deformable medium is viscoplastic; 2) matrix, punch are elastic, rolls are rigid (incompressible); 3) the contact friction stresses are proportional to the contact normal stresses.

The following quantities were determined when solving the three-dimensional problem: 1) the stress field; 2) the field of deformations; 3) the field of displacements.

We will consider further the results of a comparative analysis of the stress-strain state of metal during traditional stamping and the combined "rolling-stamping" process of "bottom" parts.

Determination of the stress-strain state (SSS) of a billet is not an end; SSS further allows calculating the deformation force, estimating the change in the thickness of the billet in the process of deformation, determining the plasticity resource of the material and predicting technological failures in the process of deformation.

The simulation results of the billet preparation with a curvilinear surface based on the traditional stamping process are shown in Figure 6 [1-3]. This figure shows the deformation fields after 20 and 32 steps.

The maximum strain rates reach values of 0.1. A general view of the modeled part and a graph of the change in punching force are shown in Figures 7 and 8. The maximum deformation force reaches 510 N. We have made a comparative analysis of the stress-strain state of the metal during the traditional stamping and the combined rolling and stamping" process of the "bottom" parts [4-6]. It should be noted that the use of high speed rolls and large single crimps in the rolling stand leads to the same defects as in the laboratory tests. In these cases, as has been already noted, the workpiece moves relative to the die and punch during the process.
Figure 5. Stress of the material flow (lead) of the billet.

Figure 6. Simulation of the traditional stamping process: a) the initial state; b) after 20 steps (after 1.0 sec); c) at the end of the process (in 1.6 s).

Figure 7. General view of the modeled bottom part and the strain intensity field (after laboratory punching).

Figure 8. Graph of the change in the force of deformation in the production of a "bottom" type part by the method of traditional stamping.
The force of deformation at the combined process of rolling and stamping turned out to be almost two times less (Figure 9), in comparison with the usual stamping. At the same time, the processing time of the finished product increased from 1.6 seconds (when stamping) to 2.5 seconds (in a combined process).

![Figure 9. Graph of the change in the force of deformation in the production of a "bottom" type part by the "rolling-stamping" method.](image)

**4. Summary**
An experimental study of the developed new technologies for obtaining large-sized parts with an elliptical surface has been carried out. The advantages and disadvantages are established, as well as the boundaries of effective applicability of new combined process. Verification of the results of computer simulation based on testing the technology in the conditions of a laboratory rolling mill was performed. The force of deformation at the combined process of rolling and stamping turned out to be almost two times less, in comparison with the usual stamping.

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