Evaluation of the possibility of manufacturing the cylindrical case-shaped products of hard-to-deform non-ferrous alloys by reverse extrusion

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Production in the form of hollow cylinders of various sizes with a constant wall thickness and a reach-through hole in the bottom are very common in engineering industry. Manufacturing of such goods is most efficient through various non-cutting shaping processes, among them a reverse extrusion, especially when the part is subject to increased requirements due to the specificity of application of these products. In this connection, manufacturing of the parts by extrusion looks preferable in view of the favorable deflected mode, continuity and microstructure, which are being formed during the deformation process. Since it is believed that the article is to meet the stringent requirements for strength and weight, non-ferrous alloys marked by strength are used for its production. Therefore, the question of selecting the technology modes is very pressing.

To select a rational scheme of extrusion in the view of minimal forces, stresses in the product and achieving maximum degrees of deformation, a finite element modeling of the process was performed. It is assumed that the forgings is made of AA5083 aluminium alloy. Various modes of the tube and bar stocks extrusion were considered. In particular, various temperature and speed conditions of deformation have been considered: cold volumetric deformation, hot volumetric deformation, isothermal deformation. Different process schemes were compared based on the formed deflected mode, minimal force parameters, as well as on the formation of lower stresses in the tool to ensure its durability. The obtained results can be useful as recommendations for choosing a variant of manufacturing technology for products and semi-finished products that are similar in configuration.

Key words: extrusion, heating, non-cutting shaping, force, stresses, deformations, tube stock, bar stock.

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Introduction

Goods in the form of hollow cylinders of various sizes with a constant wall thickness and a reach-through hole in the bottom are frequently used in various fields of mechanical engineering [1–4]. The production of such products is most efficient by means of different non-cutting shaping processes, which will allow to achieve significant increase in the metal recovery rate, sometimes the multiple one [5–7]. Operations of reverse or direct extrusion of a bar stock are used for manufacturing such goods, especially with thick walls. In case of using expensive and hard-to-deforme alloys to reduce the specific forces, and in order to reduce the losses of expensive material, the bar stock reverse extrusion seems to be the best method [8–11].

Research target setting

In this connection, we will consider the deformation possibility of a forgings of a cylindrical part of interest. It is assumed that the forgings is made of AA5083 aluminium alloy. Its sketch is shown in Fig. 1. It is assumed that the part has overall dimensions.

Modeling of forging processes for obtaining the listed products and semi-finished products for them is supposed to be fulfilled using the main theses of the theory of plasticity of plastoelastic, incompressible, hardening material in Qform 3D v7 software which is based on the finite element method. The billet material is AA5083. The punching temperature range is 20...450 °C. The deformation rate is 0.1...50 mm/s. The outer diameter of the part is 300 mm. The bottom thickness is 40 mm. The height of the part is 350 mm. The rheological model of the billet is plastoelastic. The number of the billet grid finite elements is 150...400 thous. The size of the finite elements is 0.2...0.5 mm.

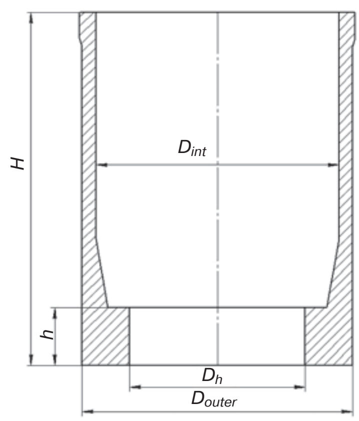

Fig. 1. Sketch of a forgings

It is preferable to manufacture the forgings of this type on hydraulic press equipment [2, 11].

Results and discussion

Let us consider various manufacturing options for the forgings involved. Its forging can be realized by the bar reverse extrusion operation (Fig. 2, *a*) or by the tube stock reverse extrusion operation (Fig. 2, *b*) under different temperature and rate conditions. We consider various options for the forgings manufacturing in order to determine the efficient ones, with relation to providing minimal forces and forming favorable deflected mode in it.

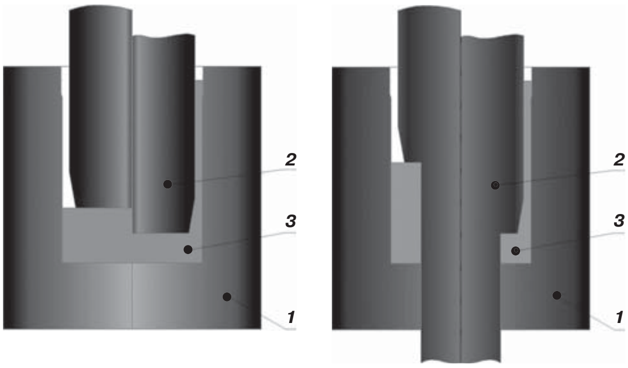

Fig. 2. Diagram of reverse extrusion:
a — bar stock; *b* — tube stock;
1 — matrix; *2* — punch; *3* — billet

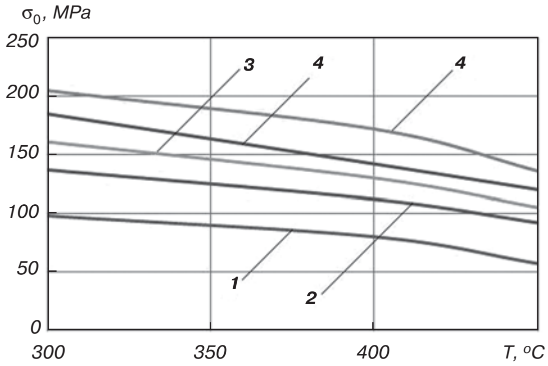

Fig. 3. Plasticity diagram:
1 — ξ = 0.01 1/s; *2* — ξ = 1 1/s; *3* — ξ = 1 1/s; *4* – ξ = 100 1/s;
5 — ξ = 200 1/s

To select the best plan for the forgings extrusion, we perform a finite element modeling of the process. The plasticity diagrams are shown in Fig. 3 [12].

Modeling to determine stresses, deformations and forces was performed for each of the considered variants of the technology. Fig. 4 shows graphic dependence that allows us to determine the process forces in accordance with the reduction value.

From the diagram in Fig. 4, it can be seen that the efficient scheme for producing the parts of the type in question, which ensures minimal force, is the tube stock reverse extrusion under isothermal conditions. It was found that the change in the temperature interval of forging significantly affects the extrusion force. So, for a bar stock, the force decreases by 15...20% on average with a change in temperature from to 450 °C, and for the tube one it is reducing by 70%. Lessening the rate also has a positive effect on the deformation force. Thus, reducing the rate from 50 to 0.1 mm/s leads to a reduction of the bar forging force in the heated state by 15%, that of the tube stock forging — by two times. The tube stock forging force is noticeably less than that for the bar one by 2...4 times. Besides, it was found that the force initially decreases slightly, and then begins to grow intensively as the reduction value increases. Efficient reduction parameters, at which minimal stamping force is observed, are set for each deformation condition.

Fig. 5 represents graphical dependence that allows to set the average normal stress in absolute value in the deformation center, according to the wall thickness ratio for different versions of the technology. Specifically, average stresses maximal in absolute values for each of the cases for the reduction values was selected in the deformation center and then they were tabulated into a summary table. The graphs presented below were constructed by these results.

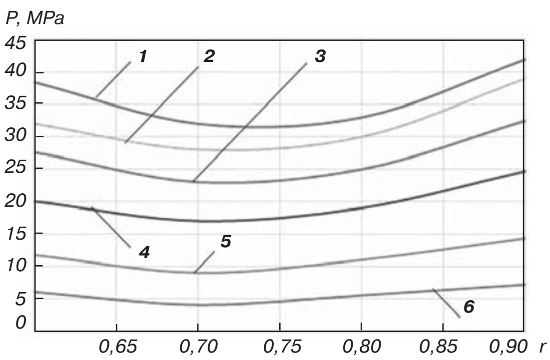

Fig. 4. Dependence of the process force of reduction:
1 — cold extrusion of a bar stock; *2* — hot extrusion of a bar stock; *3* — isothermal extrusion of a bar stock; *4* — cold extrusion of a tube stock; *5* — hot extrusion of a tube stock; *6* — isothermal extrusion of a tube stock

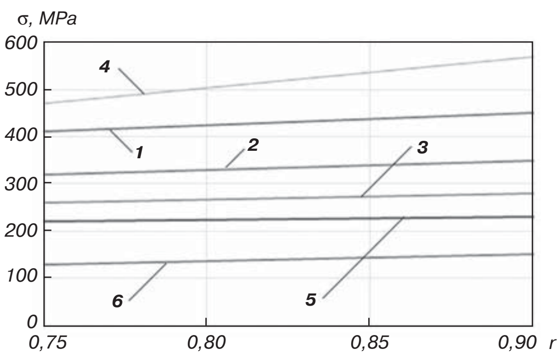

Fig. 5. Dependences of absolute maximal stresses in the deformation center of the wall thickness ratio:
1 — cold extrusion of a bar stock; *2* — hot extrusion of a bar stock; *3* — isothermal extrusion of a bar stock; *4* — cold extrusion of a tube stock; *5* — hot extrusion of a tube stock; *6* — isothermal extrusion of a tube stock

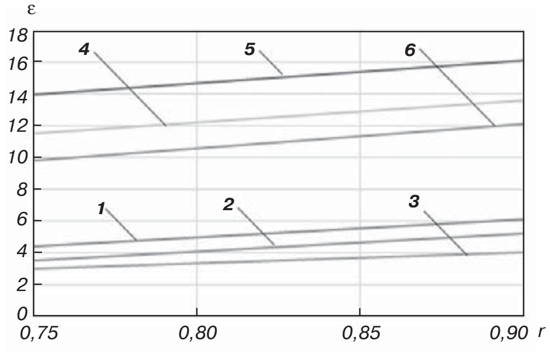

Fig. 6. Dependences of accumulated deformations in a forgings of the wall thickness ratio:
1 — cold reverse extrusion of a bar stock; *2* — hot reverse extrusion of a bar stock; *3* — isothermal reverse extrusion of a bar stock; *4* — cold reverse extrusion of a tube stock; *5* — hot reverse extrusion of a tube stock; *6* — isothermal reverse extrusion of a tube stock

From the presented dependence, one can see that stresses which are minimal in absolute value are formed in the center of deformations when implementing the tube stock isothermal extrusion. In case of the tube stock cold extrusion, there are formed the stresses which are maximal in absolute value. The difference in stresses between the bar stock extrusion and that of the tube one in the heated state is significant and is more than 70%. The stresses increase slightly as reduction increases from 0.75 to 0.9.

Fig. 6 shows graphical dependence that allows to determine accumulated deformations in the forgings depending on the wall thickness ratio for different versions of the technology.

It is clear from the dependence shown in Fig. 6, that grow of reduction leads to an increase in accumulated deformations by 15...60%, depending on the forging pattern. It can also be seen that accumulated deformations in case of the tube stock forging are noticeably greater than that for the bar one by more than two times. Analysis of the results has revealed that the deformations are maximal on the punch cylindrical part surface contacting with the billet. Their values can be lessened either by reducing the friction boundary length, or by increasing the radii of the fillets on the punch.

In addition, the values of stresses in the tool acting on the surfaces contacting with the billet are significant during the deformation process. To ensure a longer tool life, the values of these stresses have to be diminished. Use of a tube stock and its heating helps in achieving this goal. The stresses in both the matrix and the punch in case of using a tube stock are slightly less. The difference is no more than 5...10%.

Conclusions

On the whole, the obtained results make it possible to conclude that the most efficient method to manufacture cylindrical forgings with a reach-through hole in the bottom, a relatively thin wall and large dimension is the tube stock isothermal extrusion, which allows to achieve the reduction of intermediate operations and noticeable lessening in the process strength as well as provides the best deflected mode in the forgings. It also ensures some increase in material utilization if the resultant product has significant thickness of the bottom part and large hole diameter as compared with the diameter of the product. Depending on the bottom thickness and the hole diameter, the savings can amounted to 3...10%.

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