Study of the process of forming large-sized thin-walled parts

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Abstract. A method for producing large-sized parts of the bottom type, based on flanging processes, is considered. The method includes three operations for flanging different parts to be welded into a part. This allows flanging processes to be carried out using both the geometric and power characteristics of the Schuler press. The results of modeling different parts of a part with a minimum thickness difference are presented. The parameters of the flanging processes are determined.

1. Introduction

In modern conditions, the competitiveness of products is determined by a combination of the minimum production cost and high quality. There are many ways to obtain parts such as bottoms. This is due to the different functional purpose of parts, the increased requirements for their accuracy and the variety of sheet construction materials are used.

At present, a significant part of the bottoms in the industry are manufactured by cold stamping methods on presses: molding, drawing, flanging, followed by welding.

2. Investigation object

A characteristic feature of this group of bottoms is that with an increase in size, the formation of wall thinning during shaping is possible, therefore, it is necessary in each specific case to select the parameters of the stamping process by modeling the processes, finding optimal solutions.

During extraction, the loss of stability of the blank on the flange occurs in the zone free from contact with the tool. In some cases, with further shaping (after the appearance of folds) folds reach significant values. When the relative thickness of the part $S_0 / D_0 < 0.005$, which usually leads to a scrap of the part.

The dimensions of the bottom part under consideration are shown in Figure 1.
Due to its large dimensions, the part represents a relatively thin-walled shell for the processes of forming from a sheet. Therefore, its deformation must be carried out under conditions of a stressed state of tension, in order to avoid its formation.

Taking into account the existing limitations, out of several options for shaping a part from a flat blank, it is preferable to use the flanging process. The condition that ensures the stability of the flanging process is the ratio of the maximum meridional stresses.

\[ \sigma_{p\,dr} \geq \sigma_{p\,fol} \]  

where \( \sigma_{p\,dr} \) and \( \sigma_{p\,fol} \) - respectively, the maximum meridional stresses of the flat parts of the flange when leaving under the clamp and part of the blank for flanging.

For an ideal case, it is:

\[ \sigma_{p\,fol} = \sigma_s \left( 1 - \frac{r_m}{R_s} \right) \]  

The potential extraction stress of a flat flange part is ideally calculated:

\[ \sigma_{p\,dr} = \sigma_s \ln \left[ \frac{R_{\text{blank}}}{R_s} \right] \]  

\( r_m \) - is the radius of the flange hole;  
\( R_s \) - is the radius of the section of the blank when exiting under the clamp;  
\( R_{\text{blank}} \) - the radius of the edge of the blank.

Formulas (2) and (3) give estimated solutions that can be applied in the process of modeling using software products.

We divide the part into three parts, limited by sections with diameters: \( D_{kk} = 3960 \cdot 10^{-3} \) m; \( D_{mm} = 3500 \cdot 10^{-3} \) m; \( D_{nn} = 2384 \cdot 10^{-3} \) m. Their values are selected from the condition that the diameters of the blank under the clamp, with an increase in the size of the part, should decrease due to the limitation of the press dimensions. To ensure the immovability of the flange during flanging, the following conditions must be met:

\[ \frac{r_{nn}}{R_{nn}} \geq \frac{r_{mm}}{R_{mm}} \geq \frac{r_{xx}}{R_{xx}} \]

\( r_{nn}, r_{mm}, r_{xx} \) - respectively, the radius of the flange holes for parts limited by the dimensions of the joint along the sections with diameters: \( D_{nn} = 2R_{nn}; D_{mm} = 2R_{mm}; D_{xx} = 2R_{xx} \).

Figure 2 shows the scheme of forming the central part of the bottom.
\[ d_{nn} = 720 \cdot 10^{-3} \text{m}; R_{mn} = 1192 \cdot 10^{-3} \text{m}; R_{mm} = 1750 \cdot 10^{-3} \text{m}; R = 850 \cdot 10^{-3} \text{m}; r_{det \ nn} = 487 \cdot 10^{-3} \text{m} \]

1 - punch; 2 - clamp; 3 - matrix; \( R_{mn} \) - radius of part limited by section \( nn \); \( d_{nn} \) - diameter of the flare hole, limited by the section \( nn \); \( H_0 \) - height of the molded part; \( \alpha_{det} \) - angle of the length of the forming central molded part; \( r \) - current coordinates of the angle and radius of the central part;

\[ P_{clamping}, P_{flanging} \] - clamping force and flanging; \( R \) - radius of rounding of the forming central part; \( r_{det \ nn} \) - radius of the finished section \( nn \)

Figure 2. Scheme of forming the Central part of the bottom.

The scheme of flanging of the Central part of the bottom (see figure 3) is considered, taking into account the allowance for cutting the flanged end face: let’s take the height. The diameter of the flanging hole is in the first approximation from the equality of the lengths forming the flanged part of the part and the length of the forming blank with the hole free from clamping:

\[ R_{nn} - r_{nn} = R \cdot \alpha_{det} \]
\[ r_{nn} = R_{mm} - R \cdot \alpha - 3 \cdot \delta_{det} \]

(4)

It is assumed that \( r_{nn} = 360 \cdot 10^{-3} \text{m} \) and equating equations (2) and (3) we get:

\[ R_{blank \ mm} \geq R_{mn} \cdot \exp \left(1 - \frac{r_{nn}}{R_{nn}}\right) \geq \frac{2384 \cdot 10^{-3}}{2} \cdot \exp \left(1 - \frac{360 \cdot 10^{-3}}{1192 \cdot 10^{-3}}\right) = 2384 \cdot 10^{-3} \text{m} \]

(5)

Let’s take the maximum possible diameter of the blank \( D_{blank \ nn} = 4990 \cdot 10^{-3} \text{m} \)

By formula (6) we find:

\[ R_{blank \ mm} = R_{mm} \cdot \exp \left(1 - \frac{r_{nn}}{R_{mm}}\right) = \frac{3500 \cdot 10^{-3}}{2} \cdot \exp \left(1 - \frac{1192 \cdot 10^{-3}}{1750 \cdot 10^{-3}}\right) \]

(6)

\[ = 2410 \cdot 10^{-3} \text{m} \]

We accept the dimensions of the middle part of the workpiece with a diameter \( D_{blank \ mm} = 4990 \cdot 10^{-3} \text{m} \), and the hole diameter \( d_{mm} = 2200 \cdot 10^{-3} \text{m} \)

The edge part of the bottom is limited by sections with a diameter \( D_{kk} = 3960 \cdot 10^{-3} \text{m} \) and \( D_{mm} = 3500 \cdot 10^{-3} \text{m} \)

Using formula (6), we define:

\[ R_{blank \ kk} = R_{kk} \cdot \exp \left(1 - \frac{R_{mm}}{R_{kk}}\right) = \frac{3960 \cdot 10^{-3}}{2} \cdot \exp \left(1 - \frac{1750 \cdot 10^{-3}}{1980 \cdot 10^{-3}}\right) \]

(7)

\[ = 2257.3 \cdot 10^{-3} \text{m} \]

The accepted dimensions of the edge part of the blank are \( D_{kk} = 4990 \cdot 10^{-3} \text{m}, \ D_{kk} = 3100 \cdot 10^{-3} \text{m} \)

The number of intermediate anneals is calculated based on the possible breakage of the hole edge, assuming the process of deformation of the edge is similar to the process of linear stretching.

\[ e_\theta = \delta_\rho \cdot n \]

(8)

\[ r_{det \ nn} = r_{nn} \cdot e_{\delta \rho} \]

(9)

where \( N \) is a number of anneals.

For the central part of the bottom: \( N_{nn} = \frac{r_{det \ mm}}{r_{mn}} = \frac{\ln(1120)}{0.13} = 2.3 \rightarrow 3 \)

For the middle part: \( N_{mm} = \frac{r_{det \ mm}}{r_{mm}} = \frac{\ln(1070)}{0.13} = 0.61 \rightarrow 1 \)
For the edge part: \( N_{kk} = \frac{\ln |\text{det} k_k|}{\delta_k \rho} = \frac{\ln[1750]}{0.13} = 0.93 \rightarrow 1. \)

3. Modelling results
In rather time-consuming tasks, the use of modern automation tools makes it possible to exclude a significant part of routine work and to present the simulation results in a visual form [3].

To determine the stress-strain state and energy-power parameters, in the processes of metal forming by pressure, software systems based on the finite element method are widely used. The modeling uses a material with an anisotropy coefficient of a transversely isotropic body, with indicators of mechanical properties \( \sigma_{02} = 15.5 \) MPa, \( \sigma_e = 31.5 \) MPa, \( \delta_p = 0.13 \) MPa; elastic modulus \( E = 7.1 \cdot 10^4 \) MPa; the coefficient of friction is assumed to be \( f = 0.2 \). The process includes an adaptation program that reduces the elementary mesh when their neighboring elements deviate by one degree. The stain rate is 100 mm/sec. The blank is obtained by argon-arc welding and the blank is obtained by argon-arc welding from sheets with a width of 2500 \cdot 10^{-3} m with a nominal thickness of 6 \cdot 10^{-3} m. Weld width is 20 \cdot 10^{-3} m. Characteristics accepted for it: \( \sigma_{02} = 15.5 \) MPa; \( \sigma_e = 27 \) MPa; \( \delta_p = 0.13 \).

The blank has axial symmetry and 1/4 of the volume enclosed between the XOY and YOZ coordinate planes was used for the calculation (the OY axis was aligned with the symmetry axis) [3, 4, 5].

The hardening curve of the AMg6M aluminum alloy [3] is shown in Figure 3.

Thus, only the central part requires three intermediate anneals.

Modeling data - geometry, of course - element mesh, graphs of changes in thickness of characteristic elements, which are presented in (Figures 4 - 9) [6,7,8]:

**Figure 3.** The hardening curve of the AMg6M alloy.

**Figure 4.** Change in the thickness of the semi-finished product 1st transition, mm.

**Figure 5.** Change in the thickness of characteristic elements at the end of the semi-finished product of the 1st transition, mm.
Formation of thin-walled and especially thin-walled bottoms is accompanied by intense stretching. In the considered method, the thickness difference is permissible and does not exceed the minimum permissible coefficient (>10%).

The main disadvantage of the proposed option is the use of large-scale die tooling. The technology is implemented rather laboriously, but when using the flanging process by the wrapping method, the process is simplified. The proposed option in all respects fits the Schuler press.

4. Conclusion
The proposed method for the manufacture of equal-thickness parts such as bottoms using a technology based on the flanging process (tightening method) and flanging of the central part of the bottom is effective and fairly simple to implement and involves the manufacture of parts from two parts by welding.

The central part, limited by the diameter $D_{nn}$ and the spherical part, limited by the diameters $D_{kk}$ and $D_{nn}$.

In the latter case, it is possible to use strapping equipment to obtain petals, which represent the constituent elements of the spherical part (6 pieces).

The developed technique for calculating the shape and wall thickness of the part is confirmed by mathematical modeling and analytical values.

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