

Research of forming of thin-walled axisymmetric cone-shaped parts

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Abstract. This article presents a new method based on the process of beading, which allows reducing polythickness of the part wall along generatrix. The proposed method differs from known approaches in the fact that it is presented active friction forces exerted on the both surfaces of the blank. These forces are provided by usage of the elastic die and cone. This method was researched using computer simulation and experiment. In the experiment it was used the stamping tool, which implements the proposed method.

1. Introduction

Widespread application of thin-walled axisymmetric parts is stipulated by constantly growing interest in domestic industrial production in aircraft engineering. The complexity of production is associated with great labour costs and development of production techniques [1], which have great impact on final cost of product. The promising direction of resource saving technology creation is the application of new methods [2-4], which provide the production of an item with form and size come close to or relevant to finished goods, so that the number of mechanical operations is reduced, and material utilization rate is increased.

2. Investigation of the forming mechanism

A new method of beading is suggested [5] with the application of elastic elements (see Figure 1), which ensures the minimal variations on thickness. This pacing factor may be expressed as follows [6]:

$$\int_1^{\bar{R}} (S_T - S_{back})^2 d\rho \rightarrow \min,$$

where S_{back} - is the back thickness of a part;

S_T - is the technologically admissible thickness, which results from blank part shaping.

The flat blank with a hole is clamped between the container 2 and the matrix die 8, into which the elastic cone 4 is previously installed, the surface of which corresponds to the working surface of the matrix die. Then, an elastic die 3 is placed in the container. This component layout ensures that the elastic elements 3, 4 fit along the two surfaces of the blank. When the rigid die 1 is lowered, the blank is clamped between the elastic elements 3 and 4 made from rubber. With effort equal to the force of the back pressure P_{back} and the additional force from the compression of the elastic cone, the blank is beaded, changing the length of the generatrix. In this case, the pressure ensures the creation of friction



forces τ along the both surfaces, directed to the axis of the blank. They increase the tensile stresses in the elements of a larger diameter, which leads to their thinning, comparative with the edge thinning, a decrease in springing.

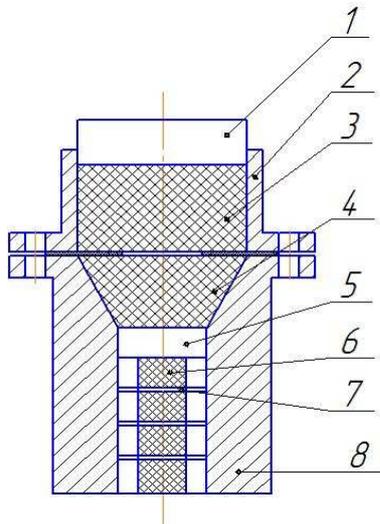


Figure 1. Forming diagram: 1- is the rigid die; 2 - is the container; 3 - is the elastic die; 4 - is the elastic cone; 5 - is the spacing washer; 6 - is the elastic cylinder component; 7 - is the laying; 8 - is the die matrix

In order to study the method and for the purpose of further experiments, modeling was carried out: from designing the stamp working surfaces to analyzing the shaping characteristics and verifying the correctness of the solution, including springing compensation [7] in the specialized, integrated and scalable Pam-Stamp 2G software package, which is used to calculate thin-walled shells and analysis of forming processes of sheet metal stamping [8]. The thickness of the blank $S_{blank} = 0.325$ mm. The friction coefficient between the tool, the blank and between the blanks, the elastic element is 0.12 and 0.09, respectively. To create pressure on the blank, the movement of the rigid die 1 had a speed less than the displacement of the washer 5. By reducing the number of finite elements and thereby facilitating the calculation process, the $\frac{1}{4}$ of volume between the XOY and YOZ coordinate planes was modeled (the OY axis was aligned with the axis of symmetry), as the assigned task is axisymmetric (see Figure 2).

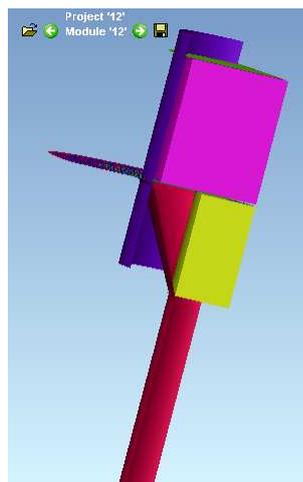


Figure 2. The kinematic model of the process

3. Experiment and simulation research

Before carrying out the experiment, the mechanic characteristics of the blank which includes: $\sigma_{0.2}$, σ_u , δ_u (see Table 1) were defined by stretching plane samples as per (GOST 7855-55) and

(GOST 1497-61), using stretching machine Tinius Olsen H5K-T and then were entered in the PAM-STAMP software.

Table 1. Mechanical characteristics for material under examination

Material	δ_u	μ	σ_u , MPa	$\sigma_{0.2}$, MPa
AD1 $S_{blank} = 0.325$, mm	0.216	0.44	167.9	61.3

As a result of calculations the values of blank thickness after forming were obtained (see Figure 3): the maximum thickness on the line of rounded radius and conic surface is 0.29 mm; the minimum thickness on the edge is 0.22 mm. Thus, variation in thickness is 24%, that is much less than variation at tool methods of thin-walled axisymmetric parts producing which is 32% [9,10,11,12].

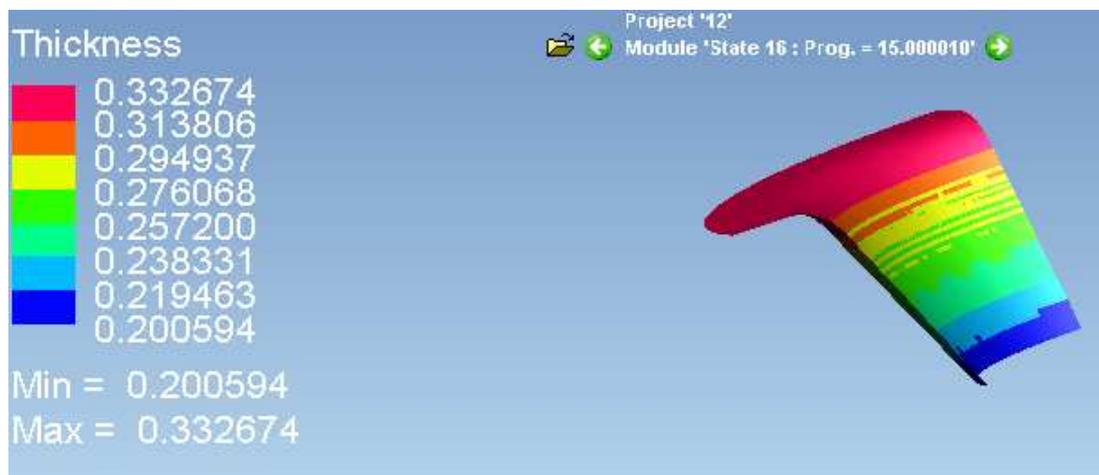


Figure 3. Simulation results

In the experiment, a stamp was used (see Figure 4), which implements the scheme (see Figure 2) in order to obtain the minimum variation in thickness of a thin-walled axisymmetric part. Blank straining was carried out at hydraulic press CDMPU -10.

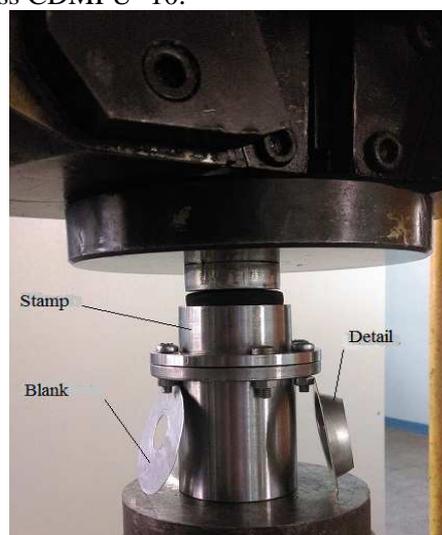


Figure 4. Experiment tool set

It should be noted that in the process of shaping, due to the internal back pressure that has arisen under conditions of all-round stretching, the elastic cone flows under the surface of the blank facing the conical part of the matrix (see Figure 5). The angle formed between the part and the matrix is $tg\alpha \leq f$, where f - is the coefficient of friction. The obtained part requires calibration in the same matrix.

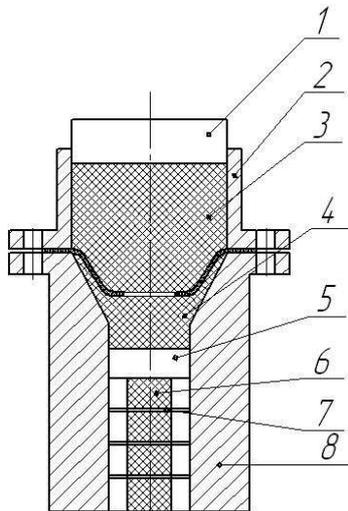


Figure 5. Forming diagram in the moment of flowing of elastic cone: 1- is the rigid die; 2 - is the container; 3 - is the elastic die; 4 - is the elastic cone; 5 - is the spacing washer; 6 - is the elastic cylinder component; 7- is the laying; 8 - is the die matrix

Before the experiment, the marking was made on the blank along the generatrix on 6 annular sections from larger to smaller diameter (see Figure 7). The blank with the following parameters $S_{blank} = 0.325$ mm; $D_{blank} = 58$ mm; $d_{hole} = 20$ mm was fixed in a stamp, with the help of screws it was fixed in the center and held down with the upper clamp. Despite the considerable pressure 8 kg/mm² from the force 200 kN with the diameter of the container $\varnothing 42$ mm, the elastic cone was not completely displaced from the blank, therefore the shape of the obtained part did not correspond to the shape of the matrix (see Figure 6). Then the part was taken out and additionally calibrated in the die tooling in use.



Figure 6. The obtained part after the flowing of elastic cone

After the final shaping on the finished part (see Figure 7) with the parameters $D_{blank} = 58$ mm; $D_{part} = 41$ mm; $d_{hole} = 27$ mm the thickness of the wall was measured along the generatrix. On the conical surface, thickness measurements were carried out with the help of an electronic indicator with an accuracy of 0.001 mm.

4. Conclusions

To clarify and confirm the advisability of using the new method, the thickness changes obtained during the experiment, in simulation, as well as in the traditional way without the use of elastic elements, are shown in Figure 7.

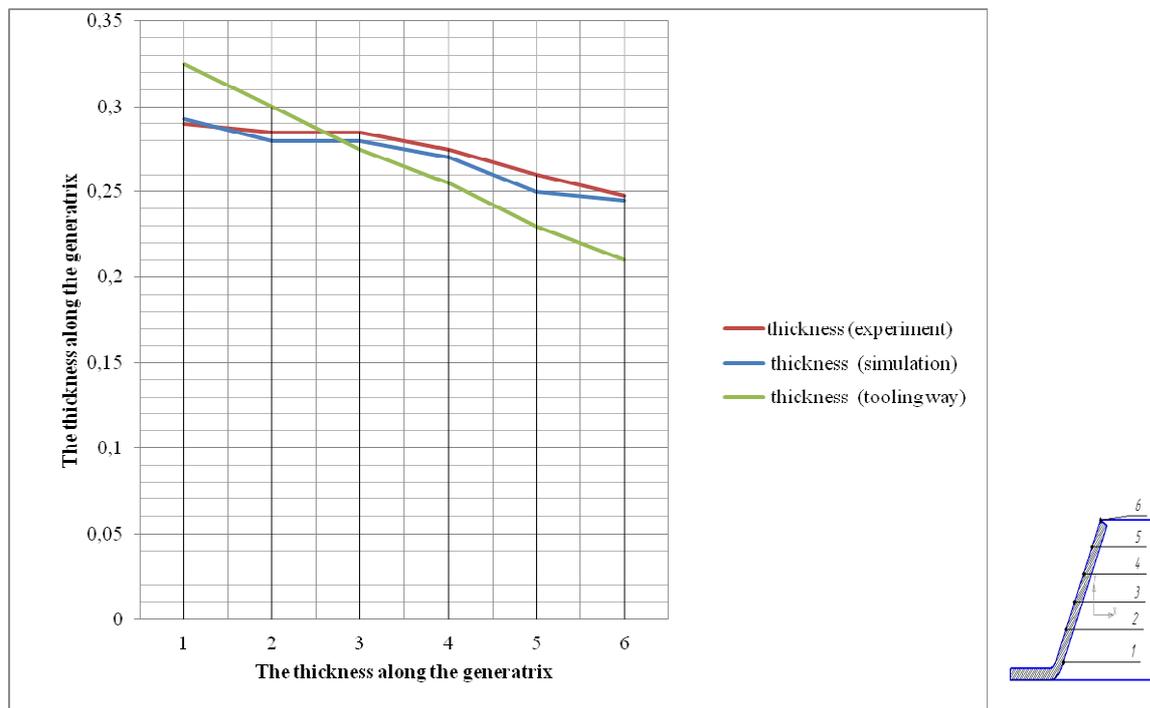


Figure 7. Changes in thickness of wall along the generatrix

The proposed method makes it possible to reduce the variation in thickness almost twofold.

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