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Experimental research of the drawing process with forced thinning of thick billet for the formation of parts with specified wall thickness

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Abstract. The modern industry development requires high efficiency from production in the area of parts manufacture. Due to this reason, it is necessary to change conical parts manufacturing technology, with cylindrical corbels, which are widely used. The paper presents the results and methods of conducting experimental studies of the drawing process with forced thinning of parts with specified wall thicknesses used in aircraft. Various types of lubricants were considered to reduce the force of the process and the distribution of the material along the generator part. Recommendations have been developed to prevent rejection of drawing operations with forced thinning of a flat thick-walled billet.

In metal forming, the problem is to obtain a stamped part, with dimensions that either close or completely correspond to the finished product. The solution to this problem allows to reduce the cost of the finished product by increasing the utilization material rate, reducing labor costs, and most importantly improving the performance characteristics of the product, which is extremely important in the manufacture of parts for aircraft engines [1].

In aircraft engines design, small-sized “nozzle” type parts of combustion chambers are widely used. At present, the production of such parts is based on technology, including the processes of cylindrical cup drawing, subsequent crimping and final machining [1]. However, this technology does not allow to obtain parts such as "nozzles" with thickenings on the edges of large and small diameters. To improve the existing technology that provides thickening on the part edges, it is proposed to use a process of drawing a flat round billet with forced thinning to make a cylindrical cup with a minimum thickness in the area, that forms a conical wall and a thicker cylindrical part of large and small nozzle diameters during compression (figure 1).

During the work, experimental studies of drawing processes with forced thinning were carried out. The following stages are considered: forming of a sheet blank into a conical matrix and subsequent drawing with forced thinning. Samples made of stainless steel 12X18H10T were used among two types of lubricant to reduce the friction coefficients of the billet with the matrix and the punch: vinyl chloride (CVL) lacquer with soapy water and Siners-V paste (TC 0254-330-00208947-2000).

Experimental equipment, was made with the recommendations set out in the works [2, 3] for the drawing process with forced thinning (figure 2). Experimental studies were carried using laboratory hydraulic press CDMU-30 with a nominal force of 300 kN in the laboratory of metalworking department (Samara University).

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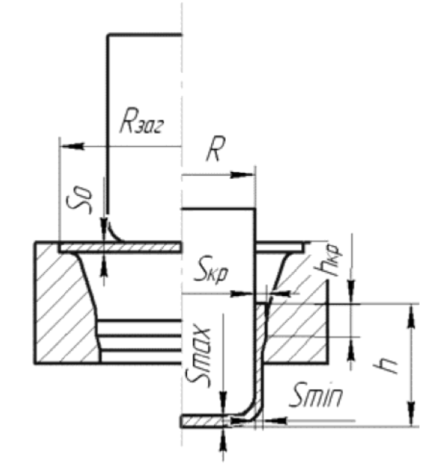

Figure 1. Diagram of the drawing process with forced thinning and subsequent crimping.

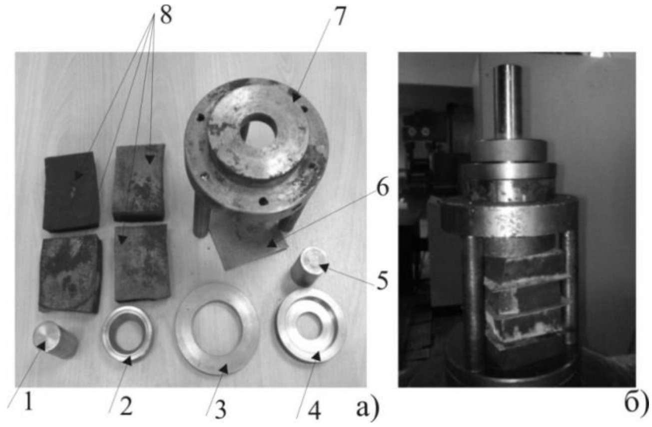

Figure 2. Tooling for drawing and drawing with forced flanging: 1 - punch, 2 - matrix, 3 - bandage, 4 - adjusting ring, 5 - ejector, 6 - gasket, 7 - container, 8 - elastic buffer, a – equipment parts for drawing, b - general view.

Flat round and ring blanks, with 2.5 mm thickness and diameter $D_{заг}$ = 50 mm, pre-drilled holes in the middle with diameters d = 11 mm, d = 13 mm, d = 13 mm, and d = 14 mm were used.

Measurement of the cut section profile of a stamped part and thickness variation is not possible with the help of a traditional indicator stand. Since the working condition of this rack requires the support and measuring tip on one axis, which is impossible in our case due to the small diameter and the presence of closed cavities in the part. One of the possible solutions to this measurement problem is to use a coordinate measuring machine (CMM). The measuring element of this machine is a ball. CMM has the ability to supply the ball from different sides due to the presence of an index able head. The measurements were carried out on a DEA Global Performance CMM with a standardized volumetric error of measurement of 1.7 + L / 333 μm, where L is the length of the measured parameter.

The control of the cut section thickness along the height of the part on the CMM was carried out in accordance with the following developed method. The control points were created on the original volumetric model, located on the same axis, the measurement of which fixes the thickness of the part in this section (figure 3). The model was developed in the CATIA software product. The basing of the part in space was provided by measuring the outer cylindrical surface having the lowest intrinsic error of shape and along the butt. Development of control programs for CMM and measurements were carried out in the software product PC-DMISCAD ++ v.4.3. Estimated distances were saved in an Excel file.

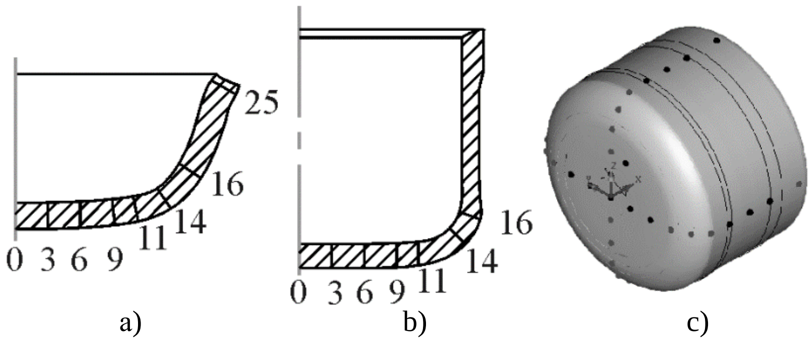

Figure 3. Cut numbering scheme: a – conical bowl, b – cylindrical cup, c – view of the original volumetric model.

During the drawing of a conical bowl into a conical matrix, CVL lacquer with soapy water and Siners-V paste were used. Table 1 shows the resulting thickness distribution in a conical bowl. The process force diagram is shown in figure 4.

Table 1. Thickness distribution in a conical bowl.

L, mm №	0	3	6	9	11	14	16	25
Cut I	2,48	2,47	2,47	2,46	2,31	2,19	2,31	2,76
Cut II	2,48	2,48	2,48	2,47	2,38	2,18	2,35	2,76
Cut III	2,48	2,48	2,48	2,475	2,35	2,19	2,31	2,75
Cut IV	2,48	2,48	2,48	2,475	2,35	2,19	2,35	2,8

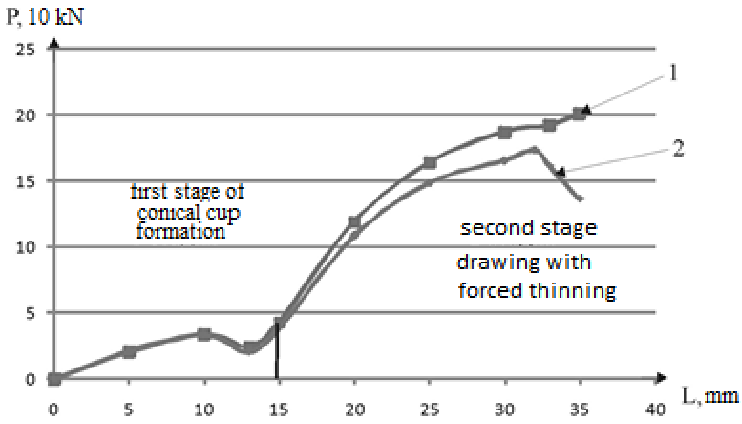

Figure 4. Force dependence on the type of lubricant: 1 – lacquer lubricant and soapy water, 2 – Siners-V paste lubricant.

The conical cup thickness distributions for both lubricants are the same. The force for shaping the conical bowl is also the same.

Figure 4, tables 2 and 3 show the obtained distributions of thicknesses on the bottom section and the dangerous section of a cylindrical cup according to the measurement scheme (figure 3) after drawing with forced thinning.

Table 2. The distribution of cylindrical cup thickness with lacquer CVL and soapy water.

L, mm №	0	3	6	9	11	14	16
Cut I	2,34	2,34	2,34	2,35	2,34	2,24	2,33
Cut II	2,33	2,33	2,33	2,34	2,33	2,22	2,32
Cut III	2,34	2,34	2,34	2,35	2,34	2,23	2,31
Cut IV	2,34	2,34	2,34	2,35	2,34	2,24	2,35

Table 3. Thickness distribution of a cylindrical cup with Siners-V paste.

L, mm №	0	3	6	9	11	14	16
Cut I	2,41	2,41	2,41	2,41	2,35	2,23	2,33
Cut II	2,41	2,41	2,40	2,39	2,33	2,25	2,32
Cut III	2,41	2,41	2,39	2,38	2,32	2,24	2,31
Cut IV	2,41	2,41	2,40	2,39	2,33	2,25	2,35

On the cylindrical section, the obtained thickness corresponds to the gap between the matrix and the punch; therefore, these thicknesses are not listed in the tables. As can be seen from the obtained data, when using Siners-V paste lubricant the stretching process force is significantly less. We can conclude that the coefficient of friction on contact pairs for these lubricants is lower than when using the traditional type of CVL lacquer with soap solution.

The thickness on the bottom section and on the section of the radius rounding of the punch using CVL lacquer and soap solution is significantly less when using the Siners-V paste.

When extracting with flanging and forced thinning, ring blanks with different hole diameters and types of lubricant were used.

Figure 5 shows the drawing process with forced thinning of the ring blank, and table 4 shows the change in the diameters of the holes upon completion of the process.

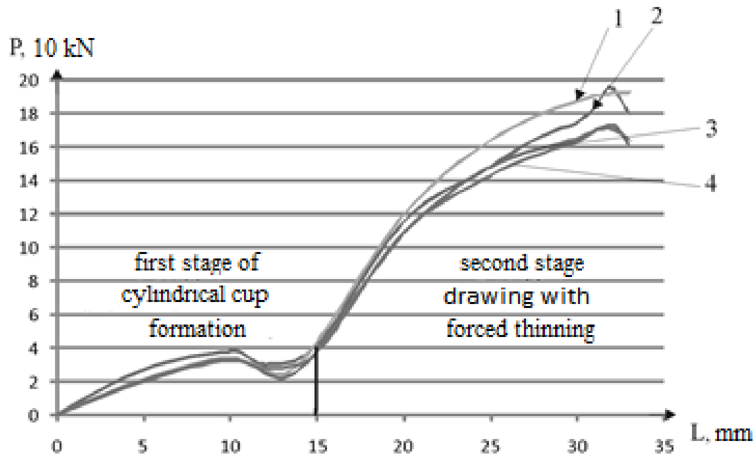

Figure 5. The dependence of the process enhancement of an annular billet drawing from the type of lubricant and hole diameter: 1, 2 – lubricant lacquer and soap solution hole diameter d_{hole} =11 mm and d = 13 mm, 3,4 – lubricant paste Siners-V hole diameter d = 11 mm and d = 13 mm.

Table 4. Billet opening diameter changes.

Original hole diameter	CVL lacquer and soap solution	Siners-V
d =11 mm	13,5 mm	12,32 mm
d =13 mm	16 mm	15 mm

When extracting with flanging and with forced thinning of the billet ring with hole diameter d = 14 mm. The full hole flanging was executed.

The main type of the defect was the edge unevenness due to inaccurate installation of the billet. The analysis allows us to formulate the following conclusions:

1. The thickness distribution on the bottom section and on the dangerous section at the conical bowl does not depend on the friction coefficient;
2. The maximum amount of thinning in the bottom part and part of the rounding radius of the punch is achieved by an drawing with forced thinning;
3. The friction coefficient on contact pairs is lower when using Siners-V paste than when using the traditional type of CVL lacquer with soapy water, this is confirmed by force diagrams and data on thickness on the bottom section and the radius rounding section of the punch;
4. The optimal lubricant is Siners-V paste, which provides a minimum reduction in the billet material thickness and the process enhancement.

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