Modeling of continuous molding process with elsatic composite working tool

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Abstract. The paper is about researchof mechanical properties of new composite polyurethane. A comparative analysis of the finite element model of the process of forming a thin-sheet product by composite and monolithic working tools is introduced. According to the simulation results, the technological aspects of the use of the composite are given.

1 Introduction

At present, in various industrial fields of mid-tech and series production, products from thin sheet metal are used, for example, heat exchanger plates, roof coverings, light aviation parts, etc. The production technology of such parts includes stamping with a rigid tool. However, the disadvantage of this method is the high cost of products and the limitation of the degree of deformation, due to which, for example, it is not possible to achieve a large channel depth for stainless steel heat exchanger plates.

As an alternative, instead of a rigid working tool, a cheap elastic tool based on elastomers is used [1–10]. The main such material is polyurethane SKU-7L. This material is the most common for stamping operations. However, the main disadvantage of this material is low normal contact stresses, which do not exceed 14 MPa even for the strongest polyurethane, which does not allow deforming steel and stronger materials with a thickness of more than 0.4 mm.

One of the ways to eliminate this problem is the use of composite polyurethane reinforced with kevlar fabric [10]. This composite has been little studied, which makes it difficult to use.

2 Material and Methods

To determine the mechanical properties of polyurethane SKU-7L, an experiment was carried out according to the scheme of pure shear in a container, presented in [6].The experiment used 2 samples:

– a homogeneous sample made of polyurethane SKU-7L with dimensions of 20x10x100 mm;

– acomposite samplewith the same dimension of the following components: polyurethane SKU-7L, aramid fabric, link – cyanoacrylate;

Figure 1 shows the dependence of the pressing force on the displacement of the punch. The upset was carried out at 4 mm, which is 20% of the initial height of the sample.

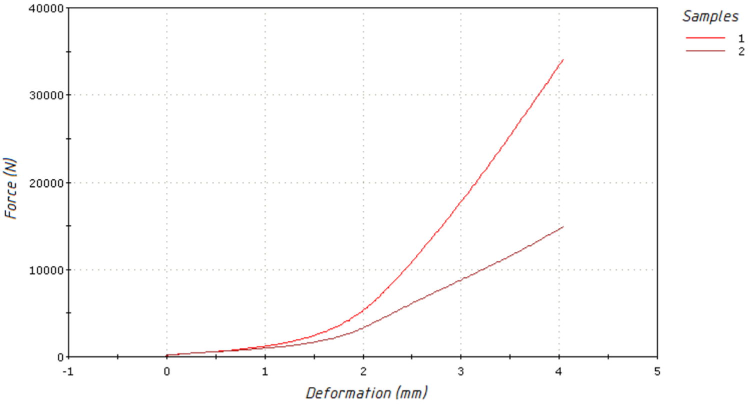

Fig. 1. Experiment result (1 – composite sample, 2 –homogeneous sample)

The force for a composite sample is 2.5 times greater than that of homogeneoussample.

After mathematical processing of the results according to the method described in [6], the Mooney-Rivlin constants were calculated for homogeneous and composite samples.

For composite polyurethane: C_{10} = 8.69 MPa; C_{01} = 2.44 MPa.

For homogeneous polyurethane: C_{10} = 2.44 MPa; C_{01} = 0.62 MPa.

The purpose of the calculation is to compare the stress-strain state of the new composite polyurethane with homogeneous polyurethane and identify its advantages, as well as its effect on the billet.

To describe the behavior of a hyperelastic material, the two-parameter Mooney-Rivlin model was adopted, which accurately describes the behavior of a material under strains not exceeding 30–50% [1-10].

The research process is based on the example of obtaining thin-sheet billets from stainless steel by the method of alternating molding. For this, a geometric model is built, shown in Figure 2.

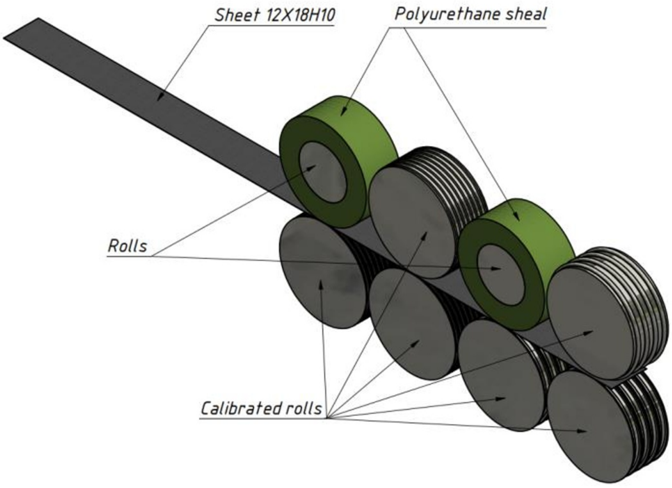

Fig. 2. Scheme of the element of the geometric model

The geometric model consists of:

– 1 caliber, consisting of a rigid calibrated lower roll and an upper rigid smooth roll with an elastic shell;
– 2 calibers, consisting of a calibrated rigid lower and upper rolls;
– 3 calibers, consisting of a calibrated lower roll, an upper smooth roll, anelastic shell;
– 4 calibers, consisting of a calibrated rigid lower and upper roll;
– sheet billet 0.4 mm thick from stainless steel 12X18H10.

Polyurethane SKU-7L is used as a material for the shell, as well as its composite analogue, the parameters for which were given earlier.

In order to optimize the calculating process, only one groove of the caliber is considered. This assumption is possible due to the significant length of the shaft - 600 mm, compared with the groove of the caliber - 5 mm.

As assumptions, it is assumed that rigid rolls do not deform; temperature influence is not taken into account; only the steady state process is considered.

3 Results and Discussion

Figures 3 and 4 show the normal stress fields of a composite tool (left) and a homogeneous tool (right) in 1 stand. The homogeneous elastic shell develops pressure on the surface of the workpiece in the zone of the flat part up to 12 MPa, in the zone of the molded protrusion up to 6 MPa. For composite polyurethane in the zone of the flat part up to 40 MPa, in the zone of the molded ledge up to 20 MPa.

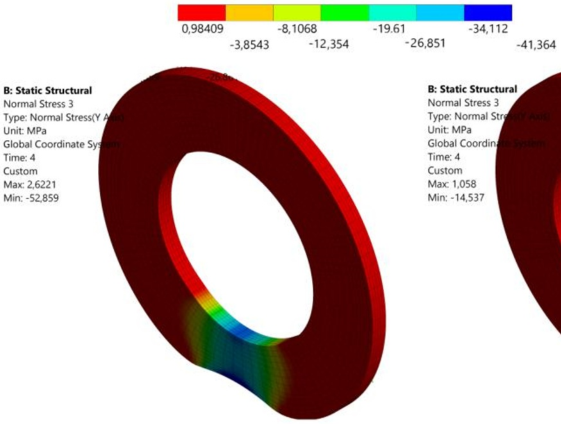

Fig. 3. Normal stress fields for reinforced (left) and monolithic (right) tools

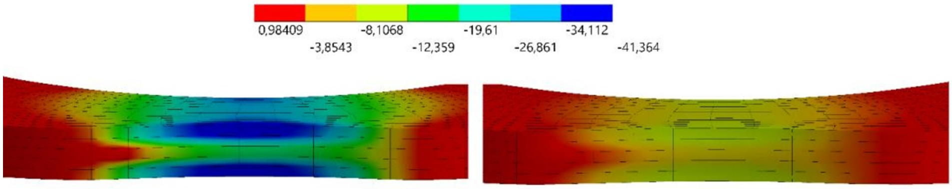

Fig. 4. Normal stress fields for reinforced (left) and monolithic (right) tools. Bottom view

By increasing the normal contact stresses, it is possible to achieve large deformations in the sheet blank in 1 pass (Figure 5). The maximum depth of the formed channel when using homogeneous and composite polyurethane is 0.24 mm and 0.74 mm, respectively.

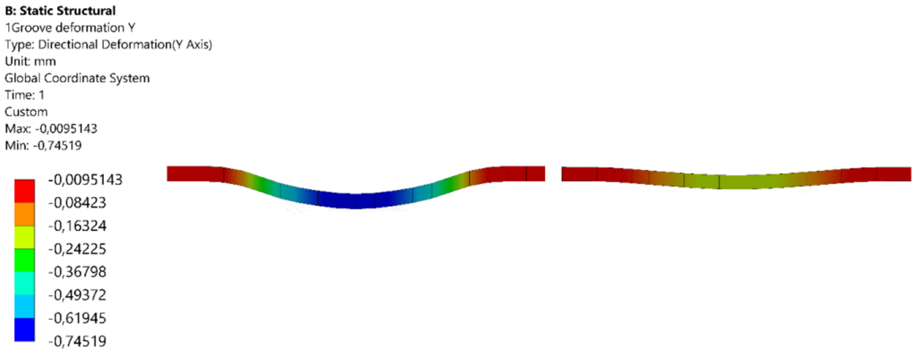

Fig. 5. Y-axis displacement fields for composite (left) and homogeneous (right) tools

Stand 2 with rigid rolls forms a channel depth of up to 1.4 mm, after which the workpiece enters stand 3 with an elastic shell.

Figures 6 and 7 show the normal stress fields in an elastic tool. It can be seen that the homogeneous elastic shell develops pressure on the surface of the billet in the zone of the flat part up to 14 MPa, in the zone of the molded ledge up to 6 MPa. For composite polyurethane in the zone of the flat part up to 52 MPa, in the zone of the molded ledge up to 20 MPa.

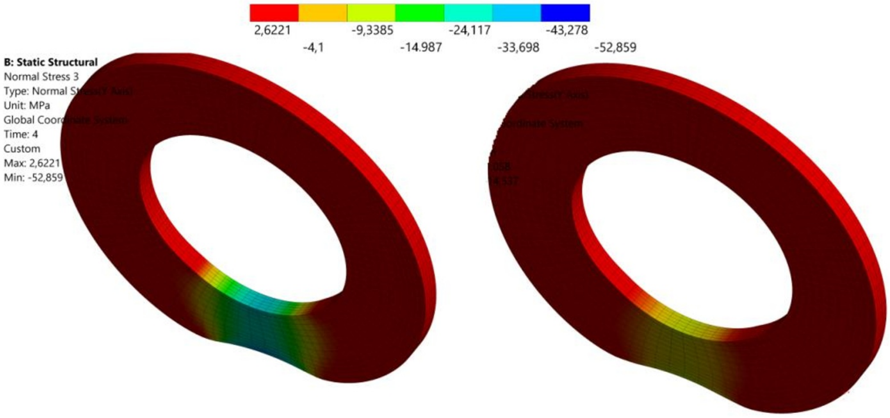

Fig. 6. Normal stress fields for composite (left) and homogeneous (right) tools

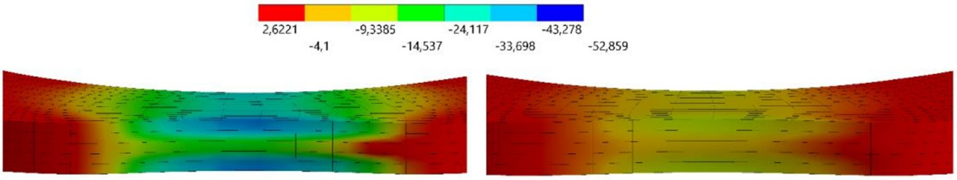

Fig. 7. Normal stress fields for composite (left) and homogeneous (right) tools. Bottom view

Figure 8 shows that, due to the increase in normal contact stresses, the maximum depth of the formed channel when using homogeneous and composite polyurethane is 2.00 mm and 3.6 mm, respectively.

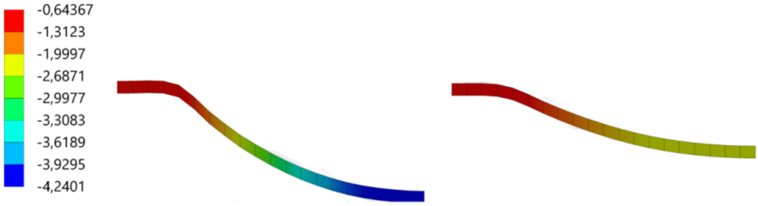

Fig. 8. Y-axis displacement fields with usingcomposite (left) and homogeneous (right) tools

The use of composite polyurethane also makes it possible to achieve a greater thickness of the billet with large deformations (Figure 9).

When using composite polyurethane, the maximum thinning of the billet occurs at the transition point between the flat and convex parts of the billet, where its thickness is 0.375 mm. At the top of the molded channel, the blank thickness is 0.39 mm.

When using homogeneous polyurethane, the maximum thinning of the billet occurs at the transition point between the flat and convex parts of the billet, where its thickness is 0.355 mm. At the top of the molded channel, the blank thickness is 0.39 mm.

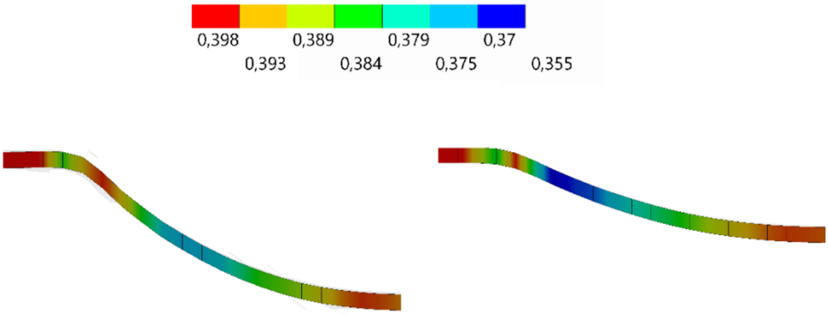

Fig. 9. The thickness of the billetwith usingcomposite (left) and homogeneous (right) tools

4 Conclusion

Comparing the results obtained, it can be said with confidence that the use of composite polyurethane can significantly increase the technological capabilities of the stamping process, molding for mid-tech and series production, while reducing the cost of production compared to when a rigid tool is used. Composite polyurethane with aramid fabric significantly increases the contact normal stresses developed by the tool, due to which stronger and more thick billets can be deformed. Also, the degree of deformation of the billet increases, due to which the number of transitions can be reduced.

It is important to note that the reinforcement of polyurethane increases the strength of the final product, by obtaining a greater thickness, which has a positive effect on the efficiency of products used in the energy industries. In this regard, it is significant to further study the technologies for the use of composite polyurethane.

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