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The influence of rib shapes on its realization in drawing process with elastic tool

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The paper deals with the drawing process by means of elastic tools. Numerical analysis of this kind of sheet metal forming were realized for chosen rib shapes. Changes of radius and rib height values were useful for technological parameters verification taking into consideration planned final parts geometry. In this work the comparison between numerical analysis results and laboratory research using 3D printing technology is presented.

KEYWORDS: elastic tools drawing, elastic tools, FEM

Introduction

The use of drawing processes with elastic tools is usually limited to a unit and a small-lot production. A good example here is the aviation industry, where sheathing sheets, sandwich panels, brackets and connecting elements are formed with elastomer punches. This technology produces fire partitions separating individual sections of the helicopter propulsion system and sheathing panels shown in fig. 1.

Fig. 1. Examples of products drawn with elastomer punches – helicopter fire partitions (top) and fixing panel (bottom)

Great advantage of the elastic stamp solution is that only one rigid die is needed to make the stamping. This significantly reduces the tooling costs and reduces production preparation time.

An additional advantage of using the elastic tools is easier – compared to traditional drawing – modernization of the shape of the product, which, for example, in aviation production, occurs quite often [1–4].

The implementation of numerical simulations using the finite element method (FEM) for the design of this type of processes allows further reduction of design time and rapid verification of the correctness of structural assumptions, taking into account behavior of the metal sheet under the load carried by elastic tool.

In the presented analysis of the drawing process using elastic tools, it was decided to run numerical simulations in the Simufact Forming software. Drawings for various shapes of ribs were verified in laboratory conditions at the Lublin University of Technology and in industrial tests. With a view to reducing the costs and verifying the possibility of using the 3D printing method, rigid tools were made of plastic. Studies have confirmed practical possibility of using this technique to produce tooling dies.

Drawing process with a use of elastic tool

In industrial conditions, the rigid matrix for the drawing process is installed on a sliding table, which moves along the guides into the working area of the press. Protective layers and an elastic diaphragm are laid on the shaped material. The flow chart of the shaping process is shown in fig. 2.

Fig. 2. Successive stages of drawing the metal sheets with elastic tools

The liquid injected into the space above the elastic punch, limited by the diaphragm, obtains the operating pressure, the value of which depends on many technological factors, such as: type and thickness of the material, depth of drawing and assumed bending radii. Additional factors hindering the process are:

- the phenomenon of springing,
- the risk of the so-called loose fields occurrence,
- possibility of introducing undesirable internal stresses.

In some cases, an annealing operation is performed in the same devices, in which the semi-products are attached to the drawing process [5–8].

An example of an Avure hydraulic press with a tunnel construction for carrying out the described drawing process is shown in fig. 3. This machine has a working fluid pressure of up to 800 bar.

Fig. 3. Industrial tunnel press Avure used in the drawing process with elastic tools

Numerical analysis of the rib drawing process with elastic tools

Numerical calculations of the process of shaping the ribs using elastic tools were carried out in the Simufact Forming software. This choice was influenced by the wide possibilities of discretization of the geometrical model of the charge. In the module intended for creating the finite element mesh – Sheet Mesh – the three-element mesh on the thickness of CP2 titanium sheet, in which the ribs were shaped, were obtained.

A calculation model prepared for simulation is presented in fig. 4. Due to the need to limit the displacement of the elastic element sideways, additional housings for this element were used. However, the main problem in such a drawing process was determining the characteristics of the elastic material.

Fig. 4. Numerical model of drawing process using elastic tool without the semi-product shown

Fig. 5. Stress-strain diagram obtained for tests with rubber punches used in industrial practice [9]

For this purpose, tests [9] were performed, in which the stress-strain relationship was determined for real material used in industrial practice and obtained for laboratory tests. The results of these analyses are shown in fig. 5 in the form of a graph and equation that have been implemented in the calculation program.

For a given numerical model, a constant friction model with a friction factor of $m = 0.3$ was adopted. The process was carried out at room temperature $T = 20\text{ }^{\circ}\text{C}$, and the tool speed was $v = 20\text{ mm/s}$. The material model with dimensions of $100\text{ mm} \times 100\text{ mm}$ was divided into approx. 34,000 elements with local mesh densities within the shaped ribs. The choice of CP2 titanium sheet was dictated by its wide application in aviation production. In the specifics of constructing plating and brackets from titanium sheets, besides the implementation of cutting-to-size processes, it is necessary to introduce ribs stiffening these very light structures.

Example results of calculations of shaping ribs with three different heights and rounding radii are given in fig. 6 together with the distribution of equivalent stresses at the end of the shaping process.

▲ Fig. 7. Device with an elastomer and steel punch (on the left) and a tool made of ABS plastic with ribs (on the right)

◄ Fig. 6. Distribution of equivalent stress in a product shaped with an elastic tool (CP2 titanium material)

Fig. 8. Comparison of experimental samples with ribs shaped in laboratory conditions

Fig. 9. Summary of the course of forces in the process of shaping ribs with the shapes shown in the figure

Numerical analysis focused on the proper mapping of the shape of the designed rib and on the values of stresses appearing in the material and which may result in its cracking. Drawing the ribs with a height of up to 2.5 mm (height increasing in steps of 0.5 mm) and rounding radii to R2, also with a value change of 0.5 mm, was analyzed. In this way, 20 cases of shaping ribs were investigated and the process limitations related mainly to material cracking were determined. This particular case relates to the problem of manufacturing the fire partitions for the aviation industry, hence the scope of research has been narrowed down to a given dimensional summary.

After performing the numerical calculations, it was decided to print the tools in the form of ABS plastic plates in a 3D printer. After printing, the tool surfaces were coated with resin to reduce roughness and reduce friction.

The device for the drawing process, punches and tools made of ABS are shown in fig. 7. As a result of laboratory tests, samples were obtained from CP2 titanium sheet with ribs reflecting the shape of the tool made of plastic. Selected samples are shown in fig. 8.

Combination of two ribs visible in the middle part was to verify the possibility of reducing the tendency to appear “loose fields” in the finished product. Research in this area will only be continued.

On the basis of calculations carried out using given material model, the processes of drawing ribs in titanium sheets were analyzed. Higher values of equivalent stresses appearing in the numerical calculations, especially at the end of the shaped ribs, were reflected in reality in the form of sheet cracking in these areas.

Fig. 9 indicates that in ribs with a rounding radius R0.5 and R1, there was a break in the sheet metal continuity, which was not observed when the bending radii increased. These values are indicative and relate only to the selected type of elastomer punch with a certain thickness. Any change in this area may affect the final results. This requires additional research related to the preparation of data for material models used in FEM software.

Summary

The use of modern FEM simulation tools in designing the shape of tools intended for drawing processes with elastic tools enables forecasting the course of selected operations. Determining the relationship between the shape of a rigid tool, elastic characteristics and dimensions (thickness) of the elastomer element and the assumptions of technological parameters of the process is still a challenge for technologists. Requirements for shaping the products with increasingly complex geometry further impede the design of technological processes. The paper does not include the possibility of using other elastomer materials as elastic tools, which will be implemented in future research on this sheet metal forming technology.

Another issue for this type of processes seems to be the use of elastic tools with a multi-stage structure, which will allow shaping products with smaller rounding radii and expand the application possibilities of this solution.

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