DETERMINATION OF OPTIMAL GEOMETRIC AND TECHNOLOGICAL PARAMETERS OF SHEET METAL REINFORCEMENT STAMPING FOR A RUBBER-REINFORCED PRODUCT "BRAKE PAD" BASED ON COMPUTER MODELING

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ABSTRACT

The article presents the results of finite element modelling of the sheet stamping process for obtaining metal fittings for a rubber-reinforced part "brake pad". DEFORM program considered obtaining a part by sequential cutting operations with punching and subsequent bending. In the process of computer modelling, the influence of various factors was studied: the type of separation operation, the gap between the die and the punch, the shape of the cutting punch, the use of lubricant, and other factors. The analysis of the results of computer modelling was carried out according to the level of deformation force. As a result, the most optimal parameters of the deformation process were identified: obtaining the initial workpiece for bending by cutting strips of strip metal; the gap between the punch and the die is 0.12 mm on each side during separation operations; the use of lubricants or punches with bevelled edges; the gap between the punch and the die in the range of 4.4 - 4.5 mm on each side, taking into account thickness of the workpiece during U-shaped bending. Performing a bending operation at the second or third stage does not have a fundamental difference in evaluating the quality of the geometry of the parts being produced.

Keywords: *finite element modelling, DEFORM, sheet stamping, cutting, punching, bending.*

INTRODUCTION

Currently, Kazakhstan continues the gradual transition of the economy from the raw materials industry to the processing industry. Now, the country has already achieved some positive results in this area. In the machine-building industry, which has a rather complex structure in Kazakhstan, including several separate industries and industries, at the present stage it is primarily characterized by an increase in production capacity and an increase in the number of entities involved in machine-building activities. And since mechanical engineering is the basis of industrial strength, economic growth in any country and the intensification of the real sector of its economy, a constant growth trend in machine-building production in the country is necessary. And first, the necessary growth dynamics of the machine-building industry in Kazakhstan, as in many other developing countries of the world, can be achieved by creating new innovative machine-building enterprises or upgrading existing ones.

Currently in Kazakhstan, as part of the implementation of the scientific project AP19679452, funded by the Ministry of Science and Higher Education of the Republic of Kazakhstan, it is planned to produce an experimental batch of rubber-reinforced products of various types, including products such as a brake pad. The brake pad is a removable element of the braking system, the working surface of which comes into frictional contact with the rolling surface of the wheel. In the production of this rubber-reinforced product, appropriate metal fittings are used, which are also planned to be manufactured in Kazakhstan from hot-rolled metal produced in the country. According to the data provided by Amkodor Elastomer CJSC (Belarus), in the manufacture of brake pads at their enterprise, an insert is used (Fig. 1), made of 4 mm thick hot-rolled rolled steel from St3 steel. The only enterprise in Kazakhstan producing hot-rolled rolled steel is Qarmet JSC (Temirtau). According to the technological instructions, which establish the technology of heating slabs, rolling and winding strips into rolls on a continuous broadband mill 1700, this mill performs hot rolling of strips with a thickness of 1.5 to 12.0 mm made of steel 08Y (this steel grade is the closest analogue of steel St3). Therefore, during the implementation of the AP19679452 project, hot-rolled sheet products from this steel grade will be used. According to classical technology, this detail is made using the following sheet stamping operations: cutting, punching and bending. These operations are carried out using a special tool - stamps [1]. At the same time, the most correct choice of the stamping method and type of stamp can be made only based on analysis and consideration of various factors, primarily economic factors, which include reducing labour and energy costs, both for the manufacture of the stamps themselves and for subsequent stamping in these stamps.

As noted above, when designing dies for sheet metal stamping, in many cases there are issues related to reducing the necessary energy consumption of the stamping process of manufactured metal products. To avoid unnecessary testing costs, methods of mathematical modelling, both hot and cold (sheet) stamping, have increasingly been used using various software products [2, 3], including such as LS-DYNA [4, 5], PAM-STAMP [6, 7], DEFORM [8, 9], Simufact Forming [10]. The use of various software products for modelling stamping processes makes it possible not only to avoid overspending the fund, but also to significantly reduce the time required for testing samples and designing stamping equipment.

The purpose of this work is to determine the most optimal geometric and technological parameters of sheet stamping of metal reinforcement inserts for the rubber-reinforced product “brake pad”, allowing to achieve a reduction in energy consumption during its stamping. Achieving this goal will make it possible to select the most efficient technological scheme for stamping this metal product from the point of view of reducing energy consumption and, accordingly, select the necessary stamping equipment with a sufficient margin of nominal force.

EXPERIMENTAL

To achieve this goal, a computer simulation of the liner manufacturing technology was carried out using sheet stamping operations in the DEFORM software package. A 4 mm thick sheet blank (according to the drawing in Fig. 1) made of 08Y steel was used as the initial blank for stamping. An adaptive type of tetrahedral grid of finite elements was applied to the blank without specifying their exact number. The key condition was to reduce the edge of the final element to 0.2 mm in the areas necessary for accurate rendering of the changing geometry. The advantage of the adaptive FE mesh is its independent “smart” distribution over the workpiece volume at each calculation step. As a result, when modelling the separation operations of cutting and punching, there is a strong condensation of elements within the deformation zones (Fig. 2).

The billet material was adopted to be isotropic and elastic-plastic, and the die material was rigid. Stamping was carried out at an ambient temperature of 20°C. The simulation was carried out with two planes of symmetry, i.e., a quarter of the workpiece was modelled. The value of the friction coefficient between the workpiece and the punch was assumed to be 0.4, which corresponds to dry

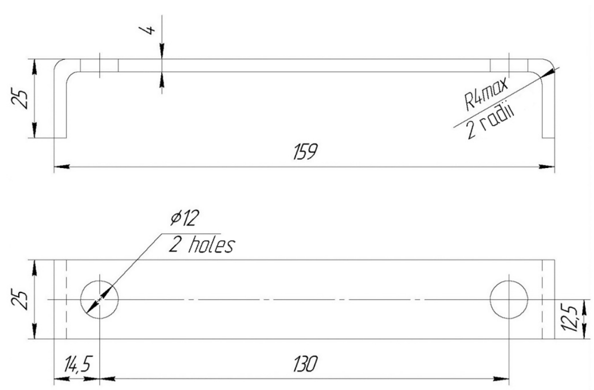


Fig. 1. Metal fittings of the brake pad.

friction without lubrication.

In the process of computer modelling, the influence of the following factors was studied:

- type of separation operation;
- the gap between the die and the punch when cutting (punching);
- the shape of the punching punch;
- the use of lubricants (different values of friction coefficients) during the cutting (punching) operation;
- U-shaped bending gap;
- the sequence of operations performed.

RESULTS AND DISCUSSION

The deformation force, as well as the shape of the workpiece, were studied as the parameters under consideration. Different type of separation operation can be applied to obtain the contour of the outer perimeter. Cutting will be required to separate the metal along the entire enclosed perimeter. The segment will be required in the special case when the width of the initial blank corresponds to the width of the part before bending. The following names were adopted in the models under consideration (Fig. 3):

1) Upper pressure plate - Top Die;
2) Lower pressure plate - Bottom Die;
3) Punching tool - Object 4;
4) Cutting tool - Object 5.

In both cases, the gap between the die and the punch during cutting and punching was 0.12 mm. Fig. 4 shows graphs of the forces occurring on all deforming elements.

Analysing these graphs, it can be concluded that the initial workpieces for subsequent bending are most efficiently obtained by cutting strips of strip metal, which is quite logical - it is less energy-consuming to cut off one side of the metal (or two if there are any defects on one side) than to cut a closed contour from four sides. In both cases, the maximum forces occur on the cutting (cutting) punches, reaching up to 270 kN when contour cutting and up to 225 kN when width cutting. It should be mentioned here that the graphs are similar in nature. First, there is a sharp peak in force, then, now when cutting the metal fibers begins, the force drops to a certain level. Further, as the separation operation continues, there is a gradual reduction in force due to a decrease in the overall resistance of the metal to separation due to a decrease in the overall thickness. When contour cutting, a large force also occurs on the lower pressure plate, which even exceeds the force on the cutting punch. When width cutting on this element, there is no great effort. The reason for this effect is that when contour cutting to the bottom plate, pressure is

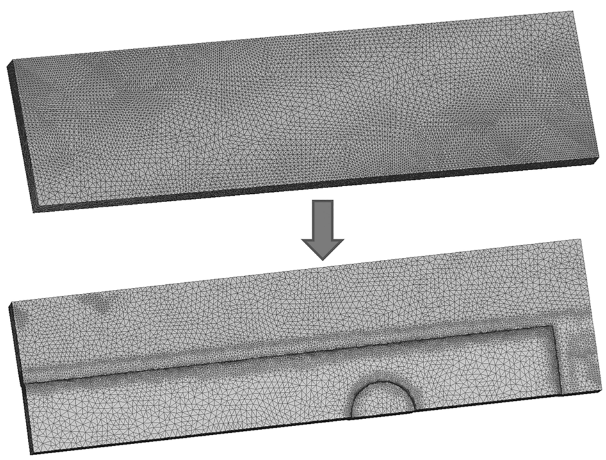
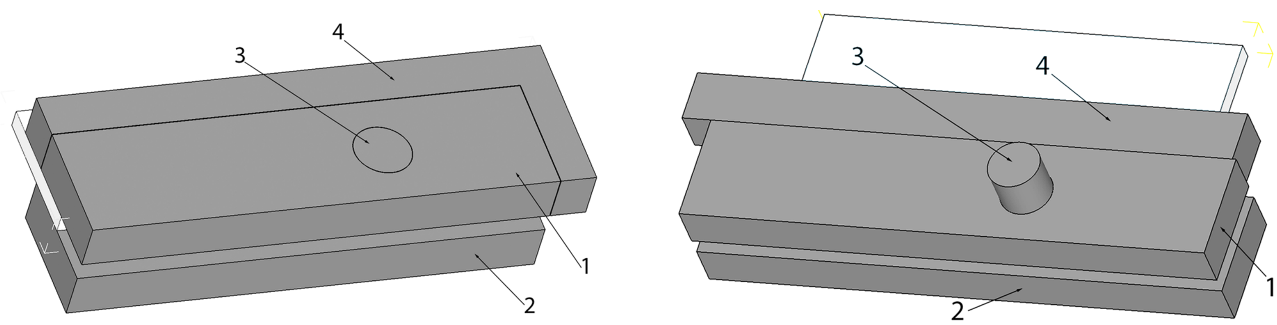


Fig. 2. Thickening of the adaptive mesh in the cutting and punching zones.



a) b)

Fig. 3. Deforming elements in the models: (a) - contour cutting; (b) - width cutting.

generated along the entire contour of the cut-out part, and the cut-out punch in the model moves vertically downward. When the punch moves back up, maximum forces will occur already on the upper pressure plate.

However, it should be borne in mind that the cutting operation is possible only in the special case when the width of the initial blank corresponds to the width of the part in the scan. In all other cases, a cutting operation will have to be performed. Therefore, it was decided to consider the contour cutting operation in the future.

To assess the effect of the gap between the die and the punch during cutting (punching), options with gaps of 0.12, 0.2, 0.4 and 0.5 mm on each side were considered. The forces were considered on a cut-out punch, since this deforming element of the model generates the greatest forces during separation operations. For convenience, a summary graph with four curves was made with identical abscissa and ordinate parameters (Fig. 5a). Analysing the results obtained, it can be concluded that during separation operations it is most advisable to use a gap between the punch and the die equal to 0.12 mm on each side. This gap provides the minimum force value at the initial stage of the cutting operation. In the future, in all cases, there is a decrease in force to about one level, which is determined by the mechanical properties of the processed material. It is also necessary to note the result obtained with a gap of 0.5 mm. This gap value, according to the recommended values of the sheet metal stamping reference books, is outside the recommended values, which are limited to 0.4 mm [11]. In this case, the force increases dramatically, reaching 290 kN. Obviously, these gap tables were compiled based on a generalization of practical data. When analysing the forces on the punching punch (Fig. 5b), their almost

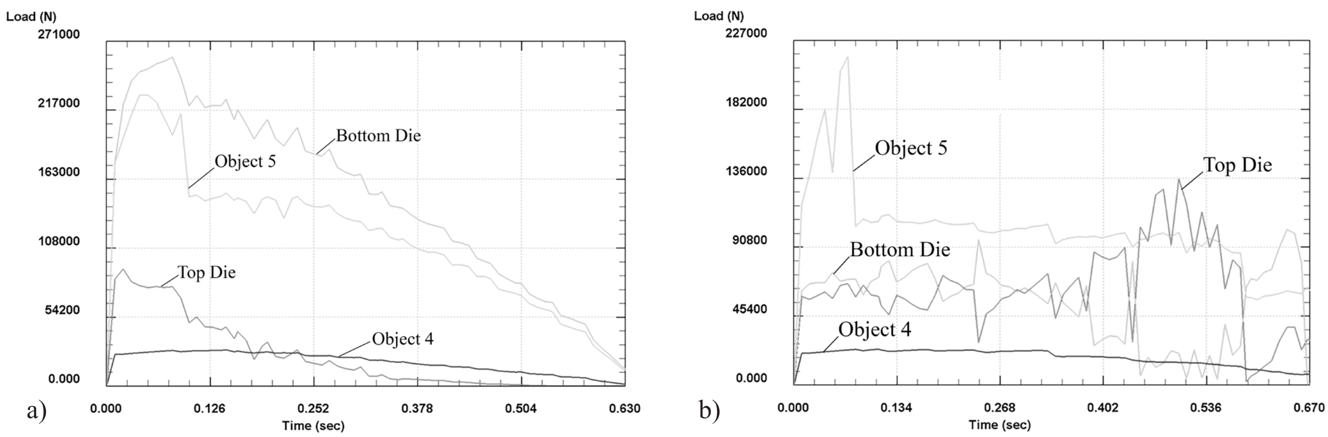


Fig. 4. Graphs of forces in the models: (a) - contour cutting; (b) - width cutting.

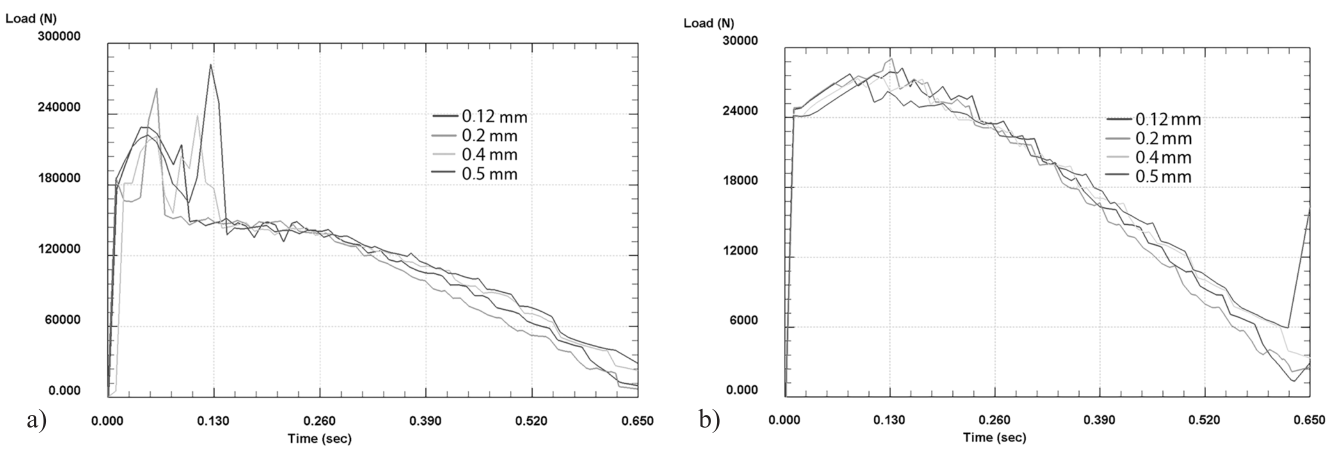


Fig. 5. Force graphs in models with different gap sizes between the die and the punch: (a) - cutting punch; (b) - punching punch.

complete identity was noted, which is due to the small diameter of the punched hole of 12 mm. In all cases, the value of the punching force does not exceed 30 kN.

In addition to straight punches, an effective way to reduce effort is to use punches with a bevelled working face. In this case, the contact surface area during the separation operation is significantly lower, which is reflected in a reduction in effort. The scheme of a punch with a bevelled face is shown in Fig. 6.

Here S - the thickness of the punched metal; H - the bevel height; φ - the inclination angle of the cutting edges. These parameters are usually taken in the range: H = (1 - 3) S; φ = 3 - 8°. To study the effect of the bevelled edges effect, the average values were taken: H = 8 mm, φ = 5°. The summary results of the effort comparison are shown in Fig. 7.

Analysing the results obtained, it can be concluded that during separation operations it is most advisable to use punches with bevelled edges, which significantly reduces both cutting and punching forces. In both cases, it was noted that the use of a punch with bevelled edges reduces the time required to separate the metal by about 20 %. This is because the bevelled face is easier to embed into the processed material. As a result of the gradual embedding of the inclined plane into the metal, faster fiber cutting occurs.

To assess the effect of lubrication on the punching force, a case was considered where the friction coefficient between the workpiece and the punches was 0.1. The summary results of the force comparison are shown in Fig. 8. Analysing the results obtained, it can be concluded that separation operations are most advisable to use lubricants. Reducing the coefficient of friction between the workpiece and the punches

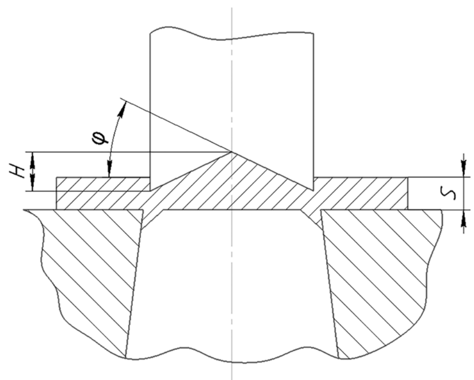


Fig. 6. Diagram of a punch with a bevelled face.

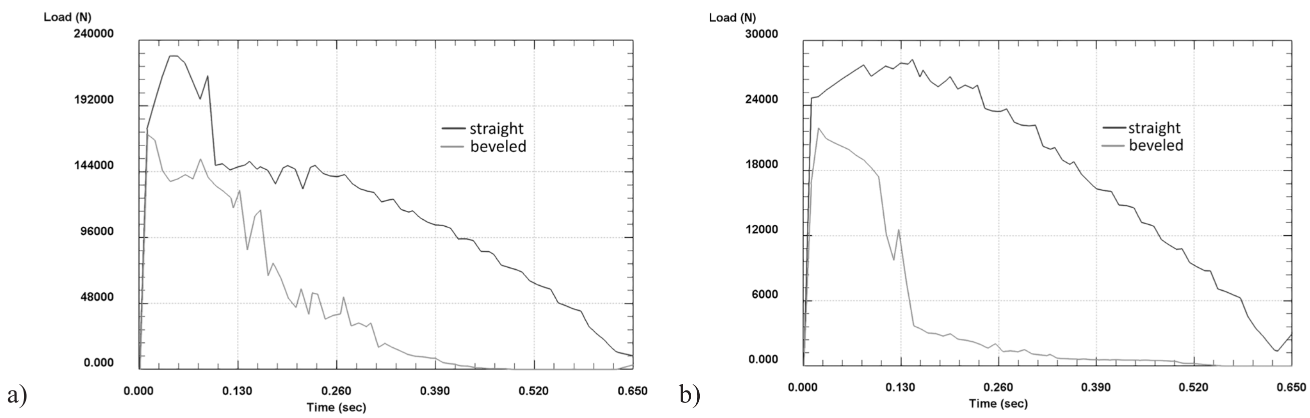


Fig. 7. Force graphs in models with different types of punches: (a) - cutting; (b) - punching.

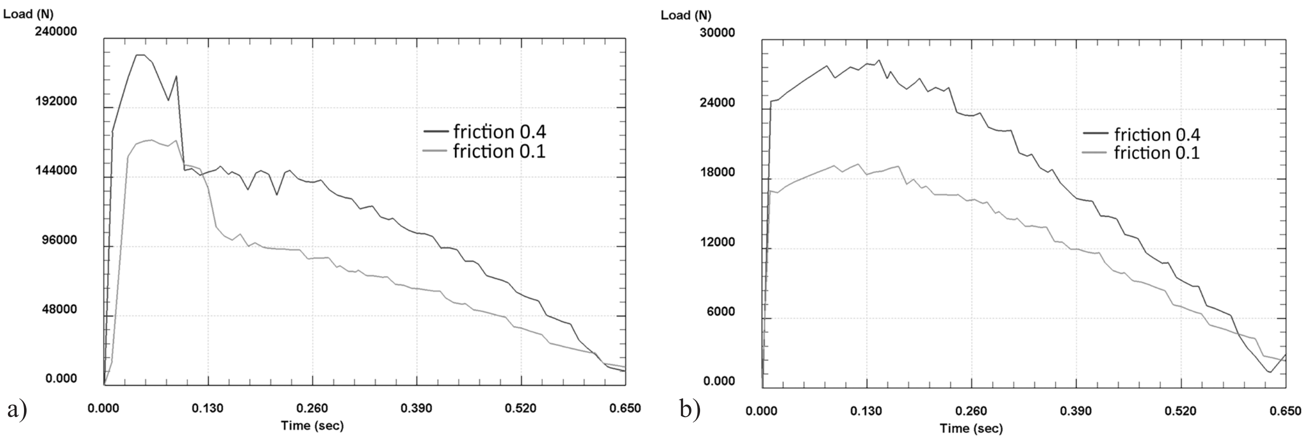


Fig. 8. Force graphs in models with different types of punches: (a) - cutting; (b) - punching.

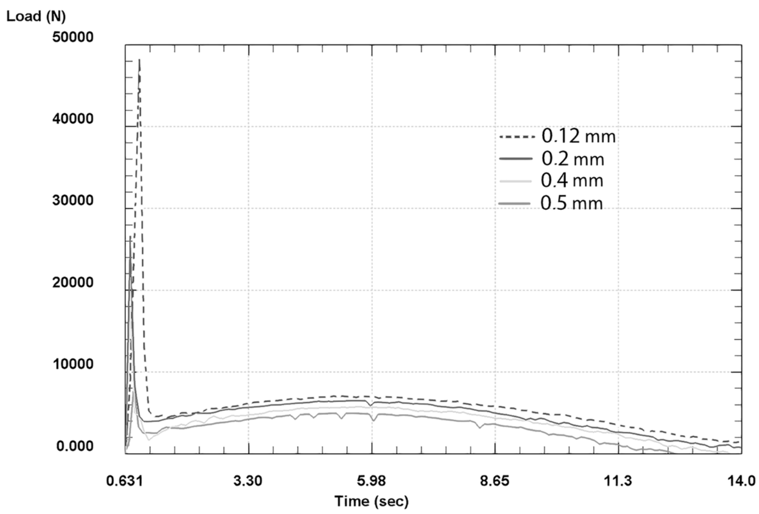


Fig. 9. Graphs of forces on a bending punch in models with different sizes of the gap between the die and the punch.

can significantly reduce the force to 25 % at the initial stage at the time of cutting the metal fibers (when the force is at its maximum), and by about 15 % during the continuation of separation operations.

After the cutting operation, the resulting workpiece is bent with a U-shaped die. Fig. 9 shows graphs of bending forces in models with different values of the gap between the die and the punch. It can be concluded that the bending operation is most advisable to use a gap of 0.4 - 0.5 mm on each side. In this case, the force values will be minimal at all stages of deformation.

The last research stage is related to the effect of the sequence of operations performed. Two cases were considered:

1) The cutting operation is combined with the punching operation, followed by the bending operation (Fig. 10a);

2) The cutting operation is performed without punching, followed by the bending operation, and only then, after bending, the hole was punched (Fig. 10b).

In the first case, there is a slight elongation of the hole (ovalization) in the horizontal direction. However, it should be noted that the level of this effect is extremely low. Therefore, it can be concluded that the sequence of operations performed does not significantly affect the shape of the workpiece hole.

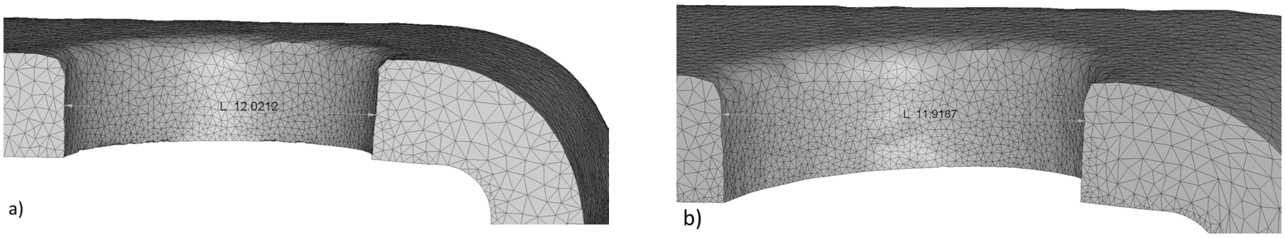


Fig. 10. Shape of the hole during different sequences of operations.

CONCLUSIONS

Analysis of the results of computer modelling has shown that in terms of reducing the deformation force, the following factors are the most optimal:

- the initial workpieces for subsequent bending are most effectively obtained by cutting strips of metal;
- for cutting and punching holes, use a gap between the punch and the die equal to 0.12 mm on each side;
- to punch, use grease or punches with bevelled edges;
- for U-shaped bending, use a gap between the punch and the die, ranging from 4.4 - 4.5 mm on each side, considering the thickness of the workpiece.

The simulation also showed that although the punched holes are located near the bending point of the workpiece, these holes have a small diameter, and the original workpiece itself has a significant thickness for sheet stamping. Therefore, the sequence of sheet stamping operations, namely: segment - punching - bending or segment - bending - punching, does not significantly affect the quality of the parts obtained.

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