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INVITED PAPER

INFLUENCE OF THE SIZE OF AN HOLE DERIVED IN THE INITIAL MATERIAL ON THE DRAWING WORKABILITY OF THE COLD-ROLLED METAL SHEETS

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Abstract

In this paper, research about the influence of the dimension to a hole derived in initial material processing with drawing the cold-rolled steel sheets is made. This influence is researched by hydraulic drawing to steel sheets with previous derived holes with different dimensions. The area between Ø 4,2 - Ø 16,35 mm is researched and corrective factor of influence to the size of the previously derived circular hole in the initial material is defined.
The goal is to proof that by changing the dimensions of the previous derived holes the processing of the cold-rolled sheets can be improved and that will help to solve technological problems in the production when the method of drawing the cold-rolled sheets with previous derived holes in the initial material is used.

Keywords: *drawing, effective deformations, effective stress, limit of deformation, continual initial material, initial material with derived holes*

1. Introduction

On the parts (pieces) manufactured by drawing from sheet steel often in their walls there are holes without meeting strict requirements for their form, position and dimensions and for different purposes such as air vents: holes for draining water and dirt, various exemptions for access to the assembly tools, forming flat surfaces near a vertical wall, etc.

Performing these holes after the process of drawing, especially in areas with a complex form is quite difficult, sometimes impossible, requiring preparation of complex and expensive tools, increases the time of manufacture, and therefore the cost of the product. It is much better and more economical if these holes are made before the drawing of the initial material.

In such cases the process of drawing is different from the process of drawing parts with continuous surfaces. The working experience with technological processes of drawing with previously performed holes in the initial material showed that very often a critical place in the process of drawing become the holes. Cracks starting from the surface of the holes appear on the drawn parts. Therefore it is necessary to study the influential factors on the workability of the cold-rolled steel sheets with drawing from the initial material with a previously derived opening.

2. Modeling of the process

The technological process of drawing cold-rolled steel sheet of an initial material with a previously derived holes which remain in the side walls of the part (piece) after the drawing is quite specific. It is assumed that the limit deformability or limit degree of drawing will be achieved when at some point in the intersection of the hazardous material will be reached a certain critical stress σ_{zmax}.

Speaking of drawing cylindrical parts of sheet metal with continuous surfaces, ie continuous initial material, the critical stress in the vertical wall depends only on how big the resistance of drawing is and equals:

$$\sigma_z = \frac{F}{\pi d s} \tag{1}$$

where:
F - strenght of drawing;
d - medium diameter of the cylindrical part and
s - thickness of the wall.

When drawing cylindrical parts with noncontiguous surfaces, ie drawing initial (starting) material with previously derived apertures the resistance of deformation depends on additional factors such as: reducing the cross-section, the size, the quality and the form of the previously derived hole in initial (starting) material etc. The influence of the additional factors can be taken into consideration by correction coefficients such as:

ξ_1- degree of reduction of the cross-section;
ξ_2- size of the previously derived hole in the starting material;
ξ_3- surface quality of the previously derived hole;
ξ_4- form of the previously derived hole;
and other corrective coefficients.

In the case of drawing parts of noncontiguous areas of a starting material with previously derived holes, the critical stress will be:

$$\sigma_{zmax} = \sigma_z \cdot \xi_1 \cdot \xi_2 \cdot \xi_3 \cdot \xi_4 \cdots = \sigma_z \cdot \xi \qquad (2)$$

The successful flow of the technological process of drawing with noncontiguous areas, as well as drawing with continuous surfaces the condition must be satisfied:

$$\sigma_{zmax} \leq (1{,}1 \div 1{,}2)\sigma_M \qquad (3)$$

where the σ_M is tensile strength of the material.

The correction coefficient for the degree of reduction in the cross-section is:

$$\xi_1 = \frac{\pi ds}{\pi ds - nls} = \frac{1}{1 - \frac{nl}{\pi d}} \qquad (4)$$

where:
n - number of holes in the critical section and
l - arc width of an aperture.

To determine the corrective coefficients of other influential factors requires additional experimental research.

For research on the impact of the size of previously derived circular hole in starting material experimental research with starting material of cold-rolled steel sheet Č 0147 (RSt 13 according to DIN 17006) with 1 mm thickness is made. At the center of three steel sheet plates with 179 mm diameter one circular hole with a different diameter at each is drilled. The surface quality of the derived holes is kept open to a constant level. Onto the steel sheet plates a measurement grid of concentric circles and radial routes that overlap with the characteristic directions of the metal sheet planar anisotropy (0°, 45° and 90°) mechanically is drawn. Onto the radial directions a circular grid with dimensions of a circle d_0 = 5 mm is drawn. Table 1 shows designations of steel sheet plates with the dimensions of the corresponding holes in the starting material.

Table 1: designations of steel sheet plates.

Steel sheet plate	Diameter of the derived opening [mm]
2.4	without opening
6.2	4.2
6.3	8.15
6.4	16.35

The experimental researches are performed by hydraulic drawing of the steel sheet. During the process of drawing as a criterion for limit deformability is considered the moment of occurrence of a crack at the aperture of the drawn part of the metal sheet plate with circular hole derived. For comparison of the results a flat steel sheet without an hole is drawn to the appearance of a crack.

Fig. 1 shows an image of a drawn piece of starting material with a derived hole with diameter 4.2 mm. The visual analysis of the cracks showed that the piece has two cracks and two localized deformations. The directions of the cracks and the localized deformations form an 45° angle with the rolling direction of the steel sheet, which means that they match the flat anisotropy characteristic direction of the steel sheet.

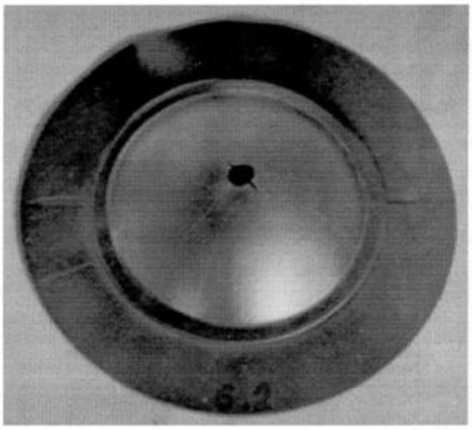

Fig. 1: Picture of a drawn piece of a starting material with a previously derived opening.

3. Meassurement and Processing of the Results

After the drawing the circles of measuring grid with diameter d_0 are deformed into ellipses with axes d_1 and d_2. The d_1 indicates the greater axis of the ellipse and lies in tangential direction and d_2 is the smaller ellipse axis and lies in a radial direction. A measurement of the ellipses' axes in the radial direction which coincides with the direction of rolling of metal sheet with an accuracy of 0,1 mm is made. This way the steel sheet anisotropy impact is avoided and it is allowed to make a comparison of the obtained stress-deformation relations for different sizes of derived holes and comparing these with stress-deformation condition while drawing steel sheet plate without derived hole.

Using the measured dimensions of the ellipses' axes are determined:

- Logarithmic deformations, and by the equations:

$$\varphi_1 = \ln\frac{d_1}{d_0}\ ,\quad \varphi_2 = \ln\frac{d_2}{d_0}\quad \text{and}\quad \varphi_3 = -(\varphi_1 + \varphi_2) \tag{5}$$

where:

φ_1 - tangential logarithmic deformation;

φ_2 - radial logarithmic deformation and

φ_3 - logarithmic deformation on the wall thickness.

- Effective deformations (deformations intensity) φ_e
- Effective stresses (stress intensity) σ_e

4. Results

The diagram Fig. 2 shows the experimentally obtained effective deformations depending on the radius of concentric circles on the measurement grids applied onto the starting flat steel sheet plates for radial direction which coincides with the direction of rolling of the steel sheet. The curve marking the change in the effective deformation of the piece drawn from the starting material without hole is marked with 2.4, and the curves of change of the effective deformation of parts drawn from the starting material with previously derived circular hole with dimensions according to Table 1 are marked with 6.2, 6.3 and 6.4. The curve 6.4 is drawn as dashed because in this process of drawing limit deformability with the emergence of a crack has not been achieved, but only the occurrence of local deformation.

The diagram shows that, the curve of change of the effective deformation of the piece drawn from the starting material without derived hole 2.4 lies higher than the other three curves. This means that a previously derived hole in the starting material influences by reducing the drawing workability of cold-rolled steel sheets. The position of the other three curves 6.2, 6.3 and 6.4 shows that starting from the outer diameter and up to ≈ 30 mm the effective deformations are equal. Starting from this diameter and until the inner aperture the deformations of parts with previously derived circular aperture are different, and the bigger the diameter the bigger the effective deformation.

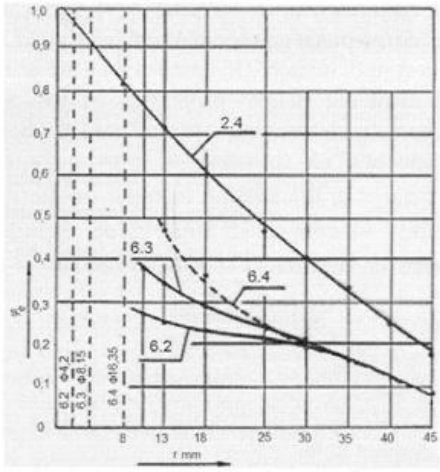

Fig. 2: Effective deformations of parts without aperture 2.4-, 6.2-aperture Ø 4,2, 6.3 aperture Ø 8,15 and 6.3 aperture Ø16, 35.

Fig. 3 shows a diagram of the change in experimentally obtained effective stresses depending on the radius of the concentric circles of the measuring grid drawn on the starting flat steel sheet for radial direction which coincides with the direction of rolling of the steel sheet. The curve marking the change in the effective stresses of the piece drawn from the starting material without hole is marked with 2.4, and the curves of change of the effective stresses of parts drawn from the starting material with previously derived circular hole with dimensions according to Table 1 are marked with 6.2, 6.3 and 6.4.

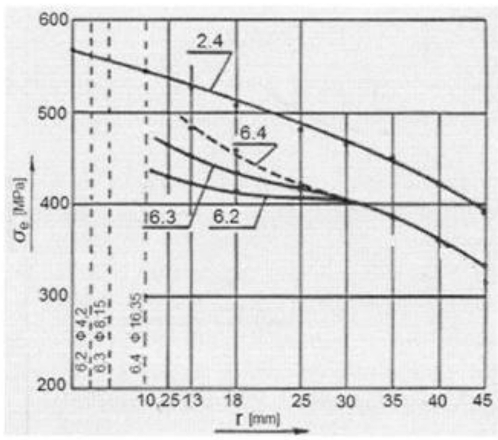

Fig. 3: Effective stresses for parts without aperture 2.4-, 6.2-aperture Ø4,2, 6.3 aperture Ø 8,15 and 6.3 aperture Ø16, 35.

From the diagrams shown on Figs. 2 and 3 we can see that the smallest effective deformations and the smallest effective stresses are obtained for the piece marked 6.2, which is made with a circular hole in the starting material with a diameter of 4.2 mm and the largest for the piece marked 6.4 with a circular hole of 16.35 mm in diameter. This means that the utilization of the available plastic properties of the material increases with increasing the diameter of the hole.
The influence of the size of previously derived circular holes in the starting material on the drawing workability of cold-rolled steel sheets expressed by the correction coefficient can be defined as:

$$\xi_2 = \frac{\sigma_{egp}}{\sigma_{eg0}}$$

where σ_{egp}- effective limit stress for a complete material and σ_{ego}- effective limit stress for a material with a derived hole.

For the researched area of circular apertures with dimensions Ø4,2-16,35 mm, the correction coefficient of the size of the previously derived hole in the starting material can be determined by the diagram in Fig. 3. The curve 2.4 is taken as an effective limit stress for a complete material and the curves 6.2, 6.3 and 6.4 as an effective limit stress for a material with previously derived circular hole.

Fig. 4 shows a diagram of the change of the correction coefficient of the size of the previously derived hole in the starting material ξ_2, depending on the dimensions of the previously derived circular hole in the starting material for the researched area.

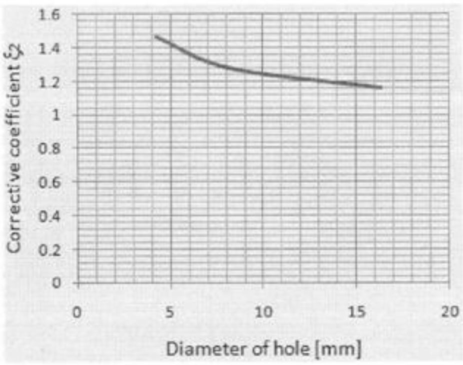

Fig. 4: Corrective coefficient of the size of the previously derived circular aperture in the starting material ξ_2.

5. Conclusions

- The derived holes in the starting (initial) material worsen the drawing workability of the cold- rolled metal sheets.
- The size of previously derived hole in the starting material impacts the use of plastic properties of the cold-rolled metal sheets when processing by drawing.
- By increasing the diameter of the previously derived hole grows the use of plastic properties of the material.
- The influence of previously derived holes in the starting material on the increases of the critical stress can be taken through the correction coefficient of the size of the previously derived holes.
- If in a technological process of making parts with derived holes in the starting material for some reason cracks appear in the process of drawing, by additionally increasing the holes in the starting material, the process of extraction can be improved and the problems overcome, but it should be taken into account the influence of the degree of reduction in the cross section.

References

[1] Strezov, V. Tehnologija na obrabotka so deformacija, Mašinski fakultet, Skopje 1982.

[2] Сторожев, М., Попов, Е., Теория обработки металлов давлением, Машиностроение, Москва 1977.

[3] William Hosford, Robert Cadell, Metal Forming Mechanics and Metallurgy Cambridge University Press New York 2007.

[4] Marciniak, Z., Dunkan, J., Hu, S., Mechanics of Sheet Metal Forming published Butterwort-Heinemann 2002.

[5] Lazarev, J., Merni metodi, merenja i obrabotka na podatoci, Mašinski fakultet, Skopje 1981.

[6] Musafija, B., Obrada metala plastičnom deformacijom. Svetlost Saraevo 1979.