

STRESS STATE IN THE PROCESS OF DEEP DRAWING OF SHEET METAL COVER AS A PART OF A CLUTCH COVER FOR COMMERCIAL MOTOR VEHICLES

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ABSTRACT

The object of this paper is a sheet metal cover from diaphragm frictional clutch cover MF 395, made from sheet metal with thickness of 5mm. Using numerical simulation and experiments, the stress distribution was determined in the technological process of the first deep drawing operation. The numerical simulation was performed using the software Simufact and the stress was determined by applying deformation analysis. A comparative analysis was made between the experimentally obtained results and the ones determined by numerical simulation.

Keywords: sheet metal cover, clutch cover, deep drawing, numerical simulation, stress, deformation.

1. INTRODUCTION

Friction clutch covers for motor vehicles represent mechanical assemblies placed between the engine and the gearbox. Their main function is to transmit the torque from the engine to the transmission. They consist of: clutch disk and clutch cover.

The cover is a part of the clutch cover. It can be made by casting or by deep drawing (sheet metal). The sheet metal covers as a part of the diaphragm clutch covers for commercial motor vehicles are made of cold rolled steel sheets by deep drawing. The thickness of the metal sheets reaches up to 7mm. The sheet metal covers are made with special tools for drawing. The cost of these special tools is high. Any

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additional correction requires additional time and therefore increases the cost. As a result, the time for implementation of the project increases as well.

The knowledge of stress and deformation distribution, including the stress of the entire sheet metal cover surface is of particular interest for the cover designers of the technological process and the constructors of the special tools for the drawing. Knowing the critical areas that occur during the process of drawing is very important, so that they can be overcome while constructing the cover and especially while designing the technological process or while constructing the special tools.

Nowadays there are different software for numerical simulation of the technological process of sheets metal deep drawing. The simulations allow designing probable technological processes, before the realization of the real process. It also allows reducing and sometimes even avoiding costly trials in real conditions.

One of the available software packages for numerical simulation of technological processes in plastic deformation is software Simufact. Using this software numerical simulation of the technological process of first deep drawing operation, as a part of a diaphragm clutch cover from the frictional clutch type MF 395, made of 5mm thick metal sheet, was performed. The stress field through the entire cover surface was determined as well. On the other hand, the stress field of the entire surface was defined experimentally using deformation analysis. A comparison of the results was made. As well, the reliability of the software for numerical simulation of technological processes for manufacturing metal sheet covers for commercial vehicles was established.

2. DIAPHRAGM CLUTCH COVER TYPE MF 395

Fig. 1 shows a photograph of the diaphragm clutch cover MF 395 and in Fig. 2 there is a photograph of a metal sheet cover for this type of diaphragm clutch cover, which is the subject of current study. The metal sheet cover is made by drawing from a cold rolled steel sheet with a thickness of 5 mm. The maximum dimensions of the metal sheet cover are: the diameter, following which the metal sheet cover leads to the flywheel 435 mm and the maximum depth of drawing 75 mm.



Fig. 1 - Diaphragm clutch cover type MF395



Fig. 2 - Metal sheet cover for MF395

3. TECHNOLOGICAL PROCESS FOR MANUFACTURING A METAL SHEET COVER FOR DIAPHRAGM CLUTCH COVER TYPE MF 395

One of the possible technological processes of making this type of metal sheet cover is by drawing from the starting material with a hole in the middle and forming in two technological operations, including:

1. First drawing after which the previously prepared starting material is formed as shown in Fig. 3 and
2. Second drawing that made the form shown in Fig. 4.

This paper refers to the stress state in the process of the first drawing of a metal sheet cover avoiding to explain other technological processes for the complete production.

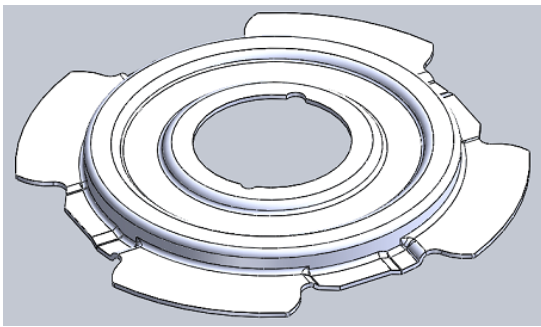


Fig. 3 - Metal sheet cover after the first drawing

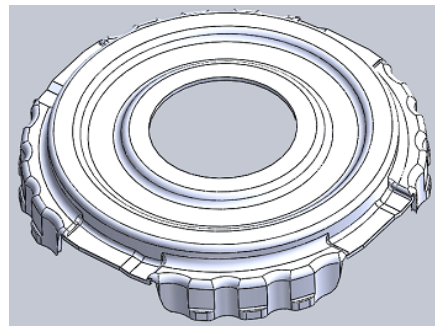


Fig. 4 - Metal sheet cover after the second drawing

4. CHARACTERISTICS OF THE MATERIAL USED IN THE RESEARCH

The research is conducted using a cold rolled steel sheet, quality Č.0147 (RSt 13 according to DIN 17 006), thickness 5 mm. An examination of the characteristics of steel sheet and certain experimental values are given in Table 1.

Table 1 - Experimentally determined characteristics of the steel sheet

Material	Upper yield stress	Tensile strength	Stress ratio	Coefficient of deformational strengthening	Coefficient of normal anisotropy
	R_{eH} [MPa]	R_m [MPa]	R_{eH}/R_m	n	r
Č 0147	283.17	346.13	0.818	0.168	0.816

Table 1 shows that the used material has a small coefficient of deformational strengthening and insufficient coefficient of normal anisotropy $r < 1$.

5. NUMERICAL SIMULATION OF THE FIRST DRAWING AS A TECHNOLOGICAL PROCESS

After defining the starting material, numerical simulation of the first drawing as a technological process was made using the software Simufact in the laboratory for plastic processing CIRKO, which is part of Faculty of Mechanical Engineering in Skopje.

Fig. 5 shows cross-section of a numerical model of the tool used for the first drawing and a drawn metal sheet cover after the numerical simulation of the first drawing as a technological process is finished.

Fig. 6 shows numerically simulated drawn metal sheet cover after the process of first drawing is finished.

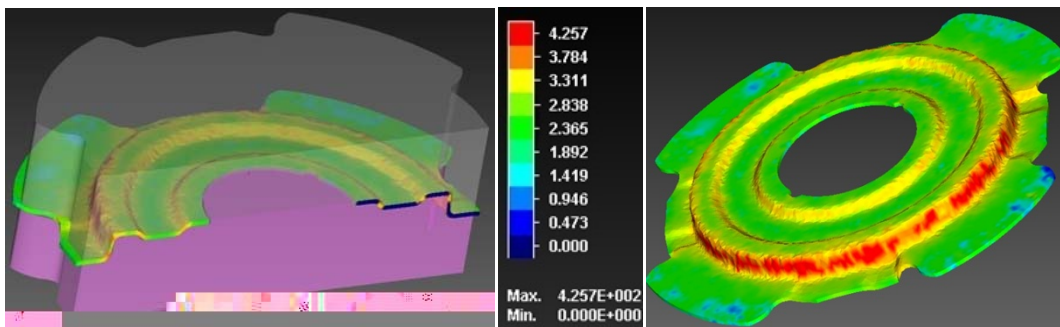


Fig. 5 - Model of the tool and the metal sheet cover

Fig. 6 - Simulated drawn metal sheet cover

5.1. Analysis of the stress state results using numerical simulation

The stress state obtained using numerical simulation is defined by the color spectrum. Fig. 6 defines very well the field of effective stress changes on the entire surface of the drawn metal sheet cover.

The Fig. 7 shows section of the metal sheet cover in radial direction passing through the surface with the maximum depth of drawing after the numerical simulating of the first drawing process is finished. In the radial direction the metal sheet cover has a depth of drawing of 34 mm.

The maximum effective stress of 425.7MPa occurs in the vertical wall that coincides with this intersection. The minimum effective stress takes place in the longer segments of the crown. At the bottom there is an increasing of the effective stress in both vertical walls. As a result of the flow of the material from the inner opening in direction to the surface of the bottom there is a slight effective stress increase on the surface limited by the internal opening and the vertical wall of the hollow of the bottom. The minimum effective stress at the bottom is on the concave plane.

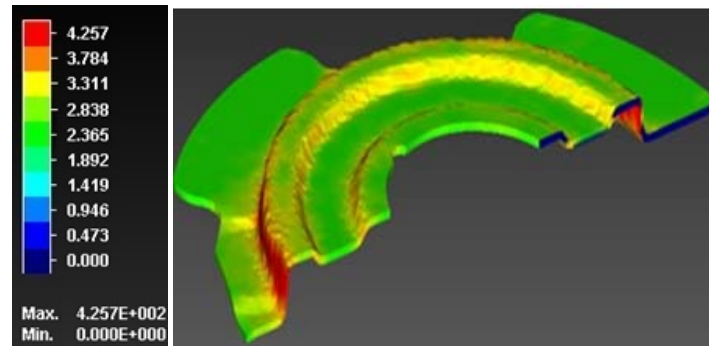


Fig. 7 - Stress determined by simulation in the intersection which passes through the maximum depth of drawing

6. EXPERIMENTAL STUDY OF THE STRESS - DEFORMACIONAL STATE OF THE FIRST DEEP DRAWING OPERATION

For the research of the stress – deformational state in the process of drawing of the metal sheet cover, two workpieces are used. The first one is cut in the direction of rolling and the other one perpendicular to the rolling direction of the metal sheet. In this way, two pieces are obtained: the first piece, whose two major segment surfaces on the external contour of the workpiece coincide with the direction of rolling while the other two are perpendicular to the direction of rolling; and a second piece whose larger segment surfaces on the external contour match the direction that covers an angle of 45° with the direction of rolling.

After cutting the starting material, on the surface measurement grid is applied. This grid consists of radial directions and concentric circles.

The technological operation first drawing was carried out in „Ruen” I.T. - Kočani with special tools, the hydraulic press HP-1000 with strength of 10000 KN and speed of drawing 0.05 m/s. The drawing was performed without lubrication oil. The process of drawing was performed using a thick metal sheet, so the tools don't need a blankholder and that is why after the drawing creases do not appear in the crown.

The Fig. 8 shows a photograph of metal sheet cover after the first drawing operation, and Fig. 9 shows a segment of the metal sheet cover with the measuring grid on it.



Fig. 8. Metal sheet cover after the first drawing

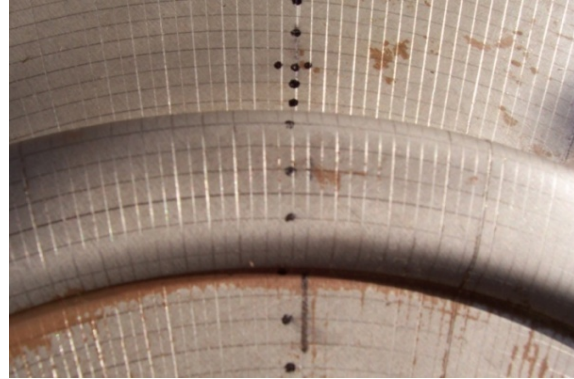


Fig. 9. Segment of the metal sheet cover with the measuring grid

6.1. Deformation after the first drawing operation

After the drawing, measurement of the deformations on the previously applied measurement grid on both metal sheet covers was made in three specific directions in the following order: the direction of rolling 0° , an angle of 45° regarding the direction of rolling and normal direction of rolling or below 90° . The measurement of both, radial and tangential lengths from the measuring grid was done with a magnifier with a precision of 0.1 mm. The arc length of the radii and the curve surfaces were measured.

The radial logarithmic deformations after the first drawing are determined by the

$$\varphi_{\rho 1} = \frac{l_{\rho 1}}{l_{\rho 0}} \quad (1)$$

where:

$l_{\rho 0}$ - is the radial length of the measuring grid of the workpiece

$l_{\rho 1}$ - is the radial length of the measuring grid in the first drawing

The tangential logarithmic deformations after the first drawing are determined by the equation:

$$\varphi_{\theta 1} = \frac{l_{\theta 1}}{l_{\theta 0}} \quad (2)$$

where: $l_{\theta 0}$ - is the tangential length of the measuring grid of the starting material, $l_{\theta 1}$ - tangential length measurement grid in the first drawing

6.2. Stress after the first drawing operation

The stresses are determined according to previously specified radial and tangential deformations measuring points for the both metal sheet covers. Since the strengthening curves for the three characteristic directions 0° , 45° and 90° nearly match, the stresses are specified only in one direction which the direction of rolling.

The ratio between the tangential and radial stresses m , the equivalent deformations φ_e , the equivalent stresses σ_e , the radial stresses σ_ρ and the tangential σ_θ stresses are determined by the following equations:

The ratio of the stresses is:

$$m = \frac{\sigma_\theta}{\sigma_\rho} \quad (3)$$

and for an anisotropic material, as is the one the covers are made of, the ratio is:

$$m = \frac{\varphi_\rho + \left(1 + \frac{1}{r_0}\right)\varphi_\theta}{\left(1 + \frac{1}{r_{\theta 0}}\right)\varphi_\rho + \varphi_\theta} \quad (4)$$

The effective deformation is:

$$\varphi_e = \frac{2}{\sqrt{3}} \sqrt{\varphi_\rho^2 + \varphi_\rho \varphi_\theta + \varphi_\theta^2} = \frac{2\sqrt{1-m+m^2}}{2-m} \varphi_\rho \quad (5)$$

The effective stress is:

$$\sigma_e = R_m e^n \left(\frac{\varphi_e}{n}\right)^n \quad (6)$$

The radial stress is:

$$\sigma_\rho = \frac{\sigma_e}{\sqrt{1-m+m^2}} \quad (7)$$

The tangential stress is:

$$\sigma_\theta = m\sigma_\rho \quad (8)$$

Now, comparison can be made between the experimentally determined effective stresses and the effective stresses obtained using numerical simulations on Fig. 10 are shown the comparative measurement points, and Table 2 shows a comparison between the experimentally determined effective stresses and the ones determined by numerical simulation.

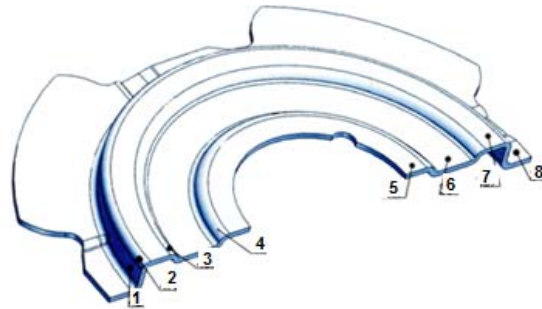


Fig. 10 - Measuring points to the metal sheet cover

Table 2. Comparison of the experimentally determined effective stresses to the ones determined with numerical simulation:

Measurement points	1	2	3	4	5	6	7	8
Experimentally determined stresses [MPa]	427	497	467	458	322	304	335	325
Stresses determined with simulation [MPa]	425	423	410	409	331	283	332	335

The conclusions from table 2 are:

1. The maximum experimental effective stress is obtained for the external fibers of the material following the radius of the passage from bottom to the vertical wall. The maximum effective stress obtained by numerical simulation is in the vertical wall and does not match the location of a maximum effective stress obtained experimentally.
2. The experimentally obtained effective stress in the vertical wall in the radial direction passing through the small crown is 427 MPa, while the effective stress obtained by numerical simulations is 425 MPa. The difference is only 0.47%.
3. The difference between the experimentally determined effective stresses and ones obtained by numerical simulations on measurement point 5 is 2,79%, on the point 6 is 7.42%, on the 7^{-th} measurement point is 0.90% and on the 8^{-th} is 3.07%. All of these measurement points lie on the flat surfaces of the drawn metal sheet cover. From the previous said, it won't be a mistake if we make a conclusion that on the flat surfaces the effective stresses match well.
4. The differences between the experimentally obtained effective stresses and the ones obtained by numerical simulations on the measuring points that lie on the radius equal 17.49%. This leads to the conclusion that the biggest effective stress deviations are on the radius. The reason for this is that a relatively thick material was used for drawing. During the experimental determination of the effective stresses the deformation is measured along the radius external fibers.

7. CONCLUSIONS

1. The experimentally obtained effective deformations at the bottom of metal sheet cover after the first drawing are minimal. There is a certain increase of the effective deformations in the radii of passage from one plane to another, but according to their size these deformations are not critical. The process of deformation is done by stretching in tangential and radial direction.
2. The experimental determined effective stresses on the surface of the bottom of the metal sheet cover are proportional to the effective deformation. The smallest effective stress has the concave flat surface. The surface of the bottom beside the inner aperture has a slightly bigger effective stress. On the radii of passage to the concave surface the effective stress increases. The effective stress increases on the radii of the transition from concave to the convex surface.
3. The radius of transition from the bottom to the vertical wall, measurement point 2 in the process of the first drawing is a critical deformation. This critical deformation contains localized deformation

(deformation above the maximum steady deformation) following the external radius fibers, but is far from deformations that would cause cracks (tearing). The size of this deformation applies only to external fibers lying on the arc of the radius. Going toward the center of the radius the deformation is reduced.

4. The effective deformations in the vertical wall are higher compared to the ones on the bottom. The maximum effective deformations in the vertical wall are above the four deepest drawn segment areas. The size of the effective deformations in the vertical wall is in the range of stable plastic deformation.

5. The effective deformations in the crown of the metal sheet cover after the first drawing are minimal. The process of deformation is done with a minimal stretching in the radial and a minimum compression in the tangential direction. The stresses in the crown are the slightest.

6. The location of the maximum effective stresses experimentally determined and by numerical simulation is in different places. The maximum effective stress determined experimentally goes along the external fibers of the radius of passage from the bottom to the vertical wall. The maximum effective stress determined by numerical simulation lies on the vertical wall. The reason for the discrepancy in the location of maximum effective stress is the fact that in the experiment the deformations are measured following the radius' external fibers.

7. For the smooth surfaces and vertical walls it will not be a mistake if a conclusion is made that there is a high occurrence between the experimentally obtained effective stresses and the ones obtained by numerical simulating on the entire surface of the metal sheet cover.

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NAPONSKO STANJE U PROCESIMA DUBOKOG IZVLAČENJA POKLOPCA SPOJNICE U KOMERCIJALNIM MOTORNIM VOZILIMA

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REZIME

Zadatak ovog rada je izrada poklopca spojnice MF 395, napravljene od lima metala debljine 5 mm. Pomoću numeričkih simulacija i eksperimenata određeno je naponsko stanje u tehnološkom postupku tokom prve operacije dubokog izvlačenja. Numeričke simulacije su vršene u programskom paketu Simufact, a naponsko stanje je određeno pomoću deformacione analize. U radu je dat i prikaz poređenja rezultata dobijenih simulacijama i eksperimentom.

Kao zaključak navodi se da eksperimentalno dobijene efektivne deformacije na dnu poklopca na kraju prve operacije minimalne, kao i da su proporcionalne sa efektivnim naponima. Radijus tranzicije između donjeg i vertikalnog zida je kritičan sa stanovišta deformacije u toku prve operacije. Takođe se navodi da su efektivne deformacije na vertikalnom zidu značajno veće nego na dnu.

Ključne reči: *poklopac od lima, spojnica, duboko izvlačenje, numerička simulacija, naponi, deformacije*