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SIMULATION OF THE RESIDUAL STRESS DISTRIBUTION IN THE CASE OF DRAWN PARTS MADE FROM METAL SHEETS

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Abstract: *The experimental investigation of the residual stress distribution in the case of draw parts is a difficult problem because of complexity of the forming operations and formed parts geometry. A solution to the problem can be the simulation of the forming process and residual stress distribution. The present paper investigates the distribution of the residual stresses by simulating the drawing process in the case of a rectangular part made in homogeneous and heterogeneous steel sheets.*

Key words: *forming simulation, residual stresses distribution, deep drawing, metal sheets.*

1. INTRODUCTION

The residual stresses that occur in the machined parts after the removing of the tools are the main cause that determines the springback of the draw parts made from metal sheets. Hence, to investigate this instability phenomenon it must be known the state of residual stresses developed in the part by its machining. But, the experimental investigation of the residual stress distribution in the case of draw parts is a difficult problem because of complexity of the forming operations and formed parts geometry. An efficacious method proposed and used by Chandra (1993) and LMECA-ESIA Annecy consists in the experimental control of residual stresses for a simple case (method of three bars) and the comparison of results with those obtained from simulation. The experimental device used in investigation is shown in Fig. 1. The methodology consists in the tensile testing of the three bars having different dimensions for determination of residual stresses.

The simulation was performed using the ABAQUS software in the same conditions like those used in experiment. The results obtained from experiment and simulation are presented in Fig. 2. From the analysis of the true stress-strain curves obtained from the both methods we can conclude that the results are similar. So a solution of the problem concerning the determination of the residual stresses can be the simulation of the forming process and residual stress distribution.

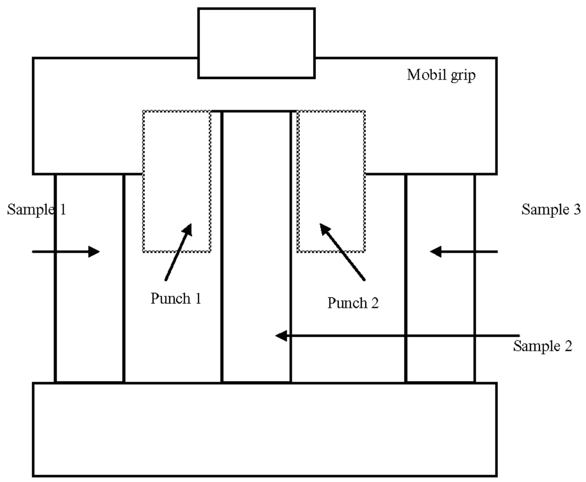


Fig. 1. Experimental device.

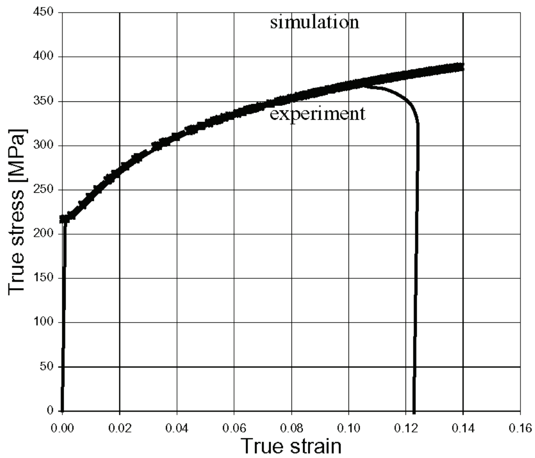


Fig. 2. True stress-strain curves obtained from simulation and experiment.

The present paper investigates the distribution of the residual stresses by simulating the drawing process in the case of different draw parts made from steel sheets.

2. CONDITIONS OF RESIDUAL STRESSES SIMULATION

The analysis concerning the residual stress distribution was performed by simulation using ABAQUS-Explicit software. The model was created in order to ensure the simulation of the quasi-static problem and to obtain the state of equilibrium after the forming operation. The simulation was performed for the parts made from: SPE 220BH and FEPO 5MBH steel sheets. The materials elastic properties for simulation were as follows: Young's modulus, Poisson's ratio and material density. A three dimensional model was used for the simulation. The blank was considered as deformable with a planar shell base. The integration method was Gaussian with 5 integration points through the thickness of the shell. The elements used for the blank mesh were of S4R type

(4 nodes reduced integration shell). The blank-holder, punch and die were modelled as rigid surfaces. Contact interactions between the blank and the tools were modelled using penalty method. The materials were considered elastic-plastic with an isotropic hardening. The working parameters were as follows: drawing speed = = 18 mm/min, blank holding force = 10 kN.

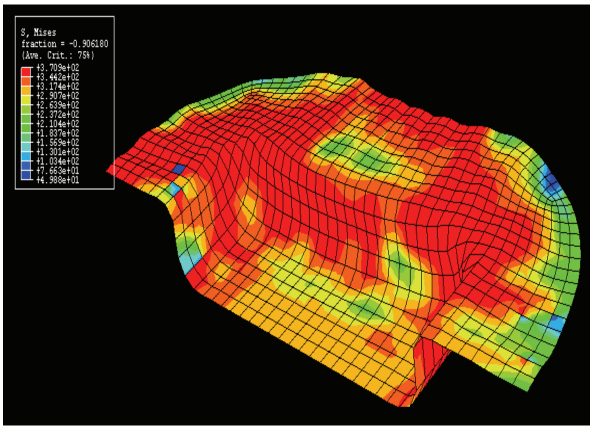
3. INVESTIGATION RESULTS

3.1. The case of rectangular parts

The results of simulation for the rectangular parts are presented in Fig. 3 – for the state of stresses resulted after drawing and springback, respectively.

The distributions of the von Mises equivalent stress on the sheet thickness and part bottom are presented in Fig. 4. By analysing the residual stress distribution on the all-draw part, the following aspects can be remarked:

- A concentration of the residual stresses can be observed after drawing in the regions of connection of the part walls with the bottom and flange that are stressed by bending; a strong concentration of residual stresses can be also observed at the corner of the parts made from both analysed materials.
- A relaxation of the stresses takes place after springback. By analysing the residual stress distribution on the bottom of the part, the following aspects can be remarked.
- The stress values vary on the sheet thickness.
- The lowest values of the residual stresses will result at the middle of the smaller edge; the greatest ones will result with the increase of the sheet thickness in the following regions of the bottom: corner, middle of the longer edge and the bottom centre.



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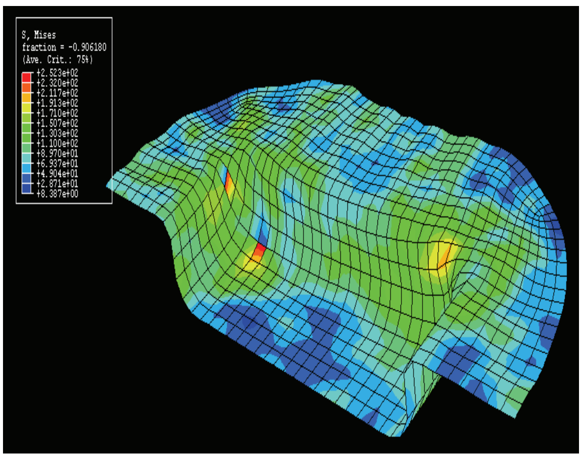

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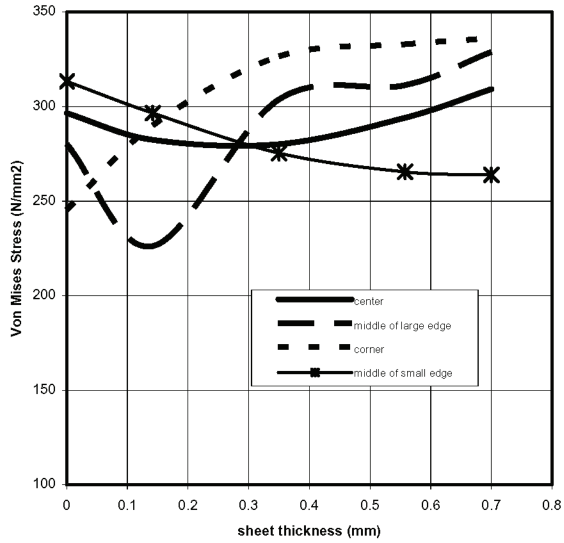
Fig. 3. State of stresses in the case of rectangular parts: a – after drawing; b – after springback.



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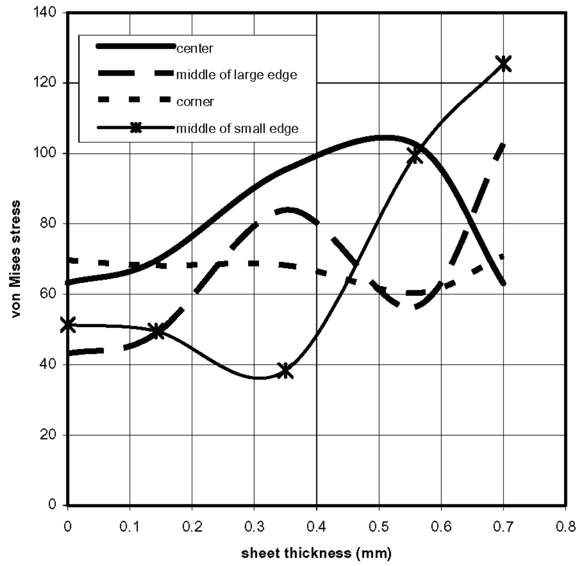

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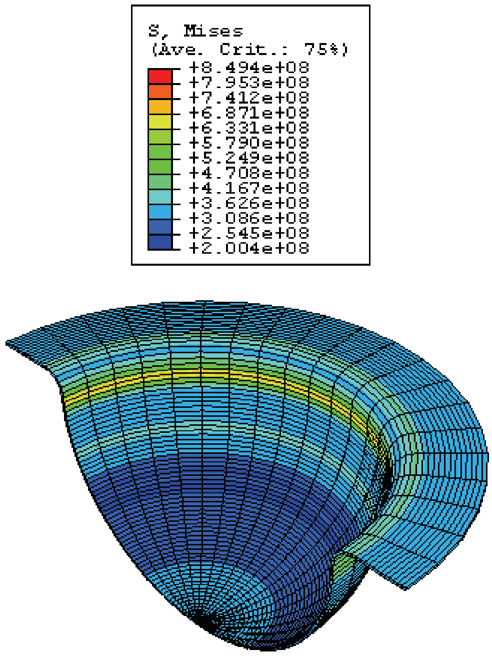
Fig. 4. Distribution of the von Mises equivalent stress in the case of rectangular parts: a – after drawing, b – after springback.

3.2. The case of hemispherical parts

The results of simulation for the hemispherical parts are presented in Fig. 5 – for the state of stresses resulted after drawing and springback, respectively. The distributions of the von Mises equivalent stress on the sheet thickness and part bottom in the case of hemispherical part are presented in Fig. 6.

By analysing the residual stress distribution on the all-draw part, it can be remarked an increase of the residual



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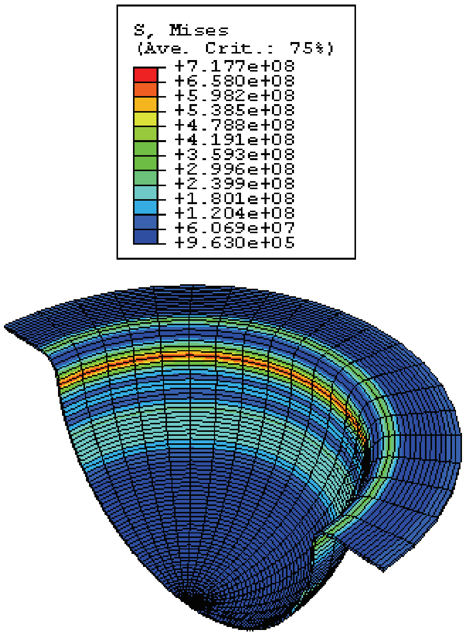

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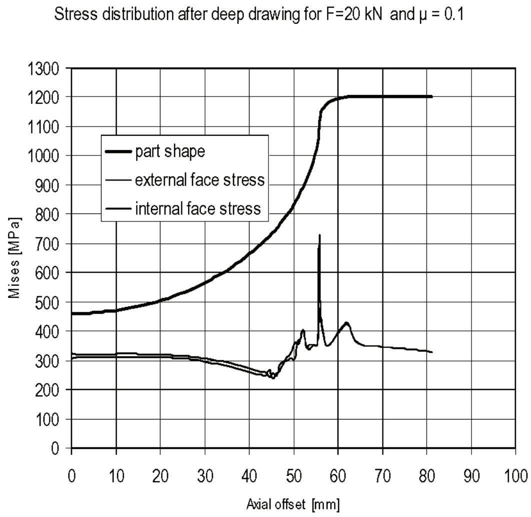
Fig. 5. State of stresses in the case of hemispherical parts: a – after drawing, b – after springback.

stress values in the region located at the zone of connection between the part body and flange.

3.3. The case of conical parts

The results of simulation for the conical parts are presented in Fig. 7 – for the state of stresses resulted after drawing and springback, respectively. The distributions of the von Mises equivalent stress on the sheet thickness and part bottom in the case of hemispherical part are presented in Fig. 8.

By analysing the residual stress distribution on the all-draw part, it can be remarked an increase of the residual



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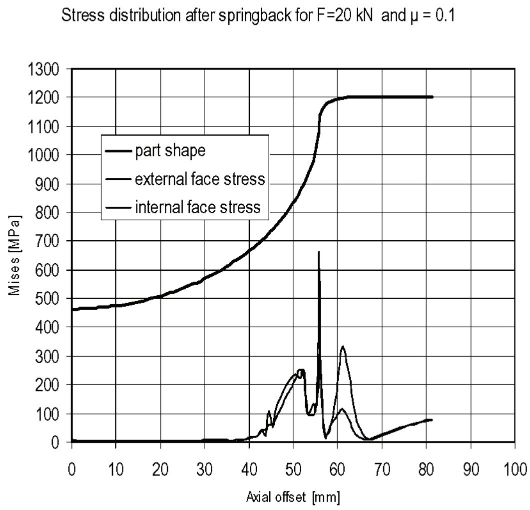


b

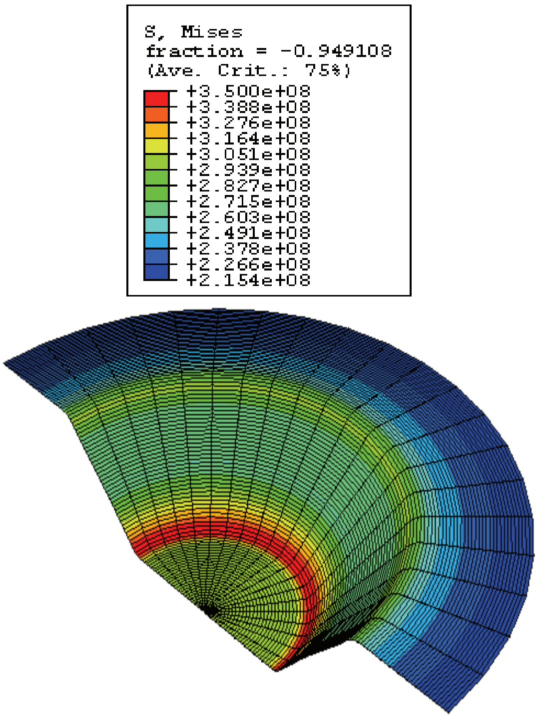
Fig. 6. Distribution of the von Mises equivalent stress in the case of hemispherical parts: a – after drawing, b – after springback.

stress values was registered in the region located at the zone connection between the inclined wall of the part and the part bottom.

4. CONCLUSIONS

By analysing the residual stress distribution on the all analyzed draw parts, the following general aspects can be remarked:

- a relaxation of the stresses it takes place after springback.
- in the case of rectangular draw parts a concentration of the residual stresses can be observed after drawing in the regions of connection of the part walls with the bottom and flange that are stressed by bending; a strong concentration of residual stresses can be also observed at the corner of the parts.
- in the case of hemispherical draw parts an increase of the residual stress values can be observed in the region located at the zone of connection between the part body and flange.



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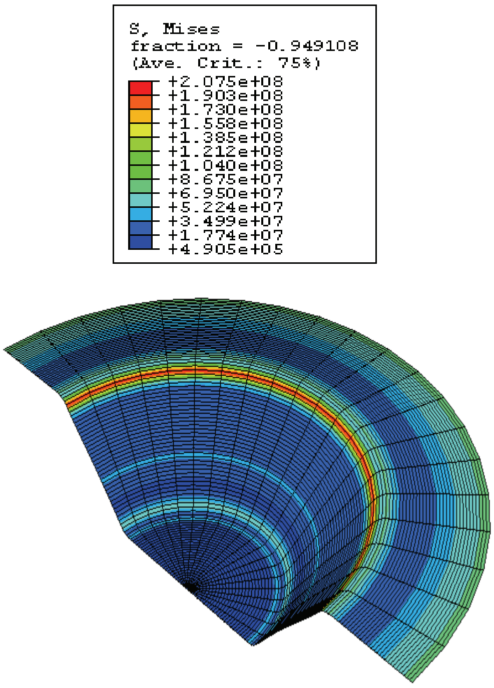

Fig. 7. State of stresses in the case of conical parts: a – after drawing, b – after springback.

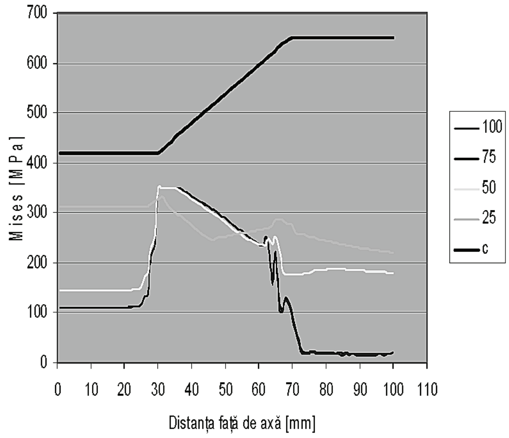

Fig. 8. Distribution of the von Mises equivalent stress in the case of conical parts for different blankholder forces.

- in the case of conical draw parts an increase of the residual stress values was registered in the region located at the zone connection between the part inclined wall and part bottom.

From the above presented aspects we can conclude that a concentration of the residual stresses can be observed after drawing for all analyzed parts in the regions of connection of the part walls with the bottom and flange that are stressed by bending; a strong concentration of residual stresses can be also observed at the corners of the parts. In all these regions were after drawing it takes place an increase of the residual stresses concentration, the springback will be characterized by higher values of its parameters.

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