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ANALYSIS BY SIMULATION OF THE STATE OF STRAINS DURING THE DRAWING PROCESS OF PARTS MADE FROM METAL SHEETS

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Abstract: *The stresses and strains generated in the stamped parts before and 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 the springback phenomenon it must be known the state of stresses and strains developed in the drawn part by the cold plastic forming. The experimental investigation of the stresses and strains distribution in the case of drawn parts is a difficult problem because of the forming tools construction and parts geometry complexity. An optimum solution to solve the problem can be the simulation of the forming process and stress/strain distribution. The present paper investigates the distribution of the strains by simulating the drawing process using ABAQUS software in the case of rectangular and cylindrical parts made from steel sheets.*

Key words: *deep drawing, state of strains, rectangular and cylindrical parts.*

1. INTRODUCTION

The analysis of the models created till present for the determination of springback parameters leads to conclusion that all such models are based on the theoretical estimation of different parameters or factors that influence the springback. The estimation is not based on an analysis of the physical phenomena that accompany the forming process and doesn't take into consideration the real distribution of the springback parameters as a function of different forming conditions [1, 2, 3]. During deep drawing process, the part material is stressed in different zones of part – as a function of part configuration – by different efforts, such: tensile, compression, bending, etc (Fig. 1).

Such efforts generate in the material, on its different stressed zones, the following effects: different states of strains and stresses, variation of the sheet thickness, different orientations of the grains, etc. [4]. The above mentioned effects will lead finally to the instability of the part geometry – especially the springback phenomenon – and to its inaccuracy. The precise determination and delimitation of the zones with nonuniform deformation will permit the accurate establishing of the fields of variation of the needed working parameters (for example the blankholder force can be applied step by step as a function of the mode of material deformation or of the state of strains and stresses developed into material on its different zones) or of the geometric parameters of the drawing tool in order to eliminate the above presented negative effects.

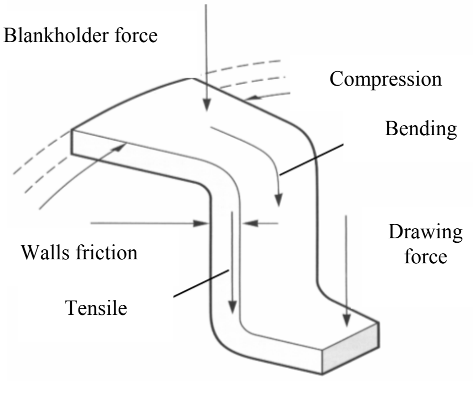


Fig. 1. Efforts that stress the material during deep drawing.

The delimitation of such zones can be only made by an investigation of the mode of material deformation and by determining the specific parameters that characterize this mode of deformation. On this basis it will be possible the springback process modelling and hence the accurate establishing of the forming parameters and tool geometry just from the designing phase and hence to eliminate the need of their future corrections.

The analysis of the mode of material deformation and the determination of its specific parameters is proposed to be achieved by applying the simulation of the process by using the ABAQUS software.

2. CONDITIONS OF SIMULATION

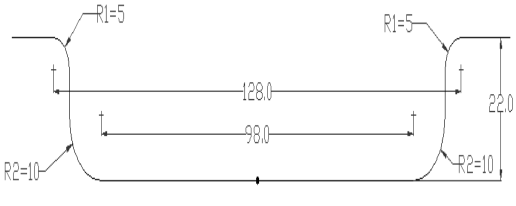
The investigation was performed for parts made from FEPO steel sheets. The materials elastic properties were as follows: Young's modulus 2×10^5 MPa, Poisson's ratio 0.3, density 7 800 kg /m^3. The material was considered elastic-plastic with an isotropic hardening.

The coefficient of friction used for the contact between blank, punch, die and blankholder was $\mu = 0.1$. The process parameters were as follows: drawing speed = 18 mm/min, blankholder force = 10 –12 kN.

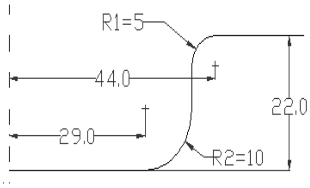
The dimensions of the finished part are presented in the Fig. 2.

The drawing process has been simulated using the ABAQUS-Explicit software. A three dimensional model (Fig. 3) used for simulation 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 part was considered deformable with a planar shell base. In simulation a quarter of part having two symmetry conditions (*yz* plane – *A* and xy plane – *B*) was used. The blank was considered deformable with a planar shell base. The integration method was Gaussian with 5 integration points for every node, equal distributed through the thickness of the shell. The elements used for the blank mesh were of CAX4I type. The blank-holder, punch and die were modelled as rigid surfaces. Contact interactions between the blank and the tools were modelled using penalty method. In order to describe the plastic behaviour of the used material, 10 points were chosen from the stress – strain diagram.

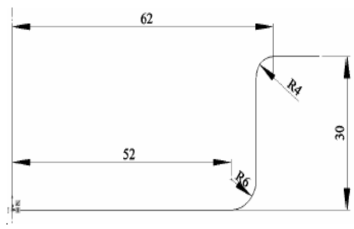


longitudinal section



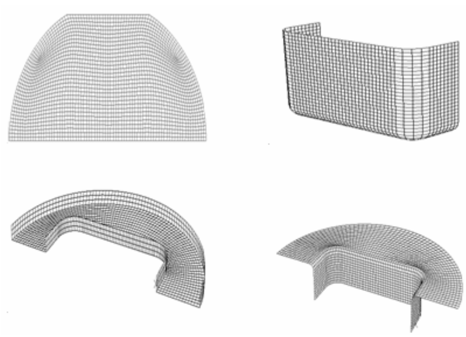
transverse section

a – rectangular part

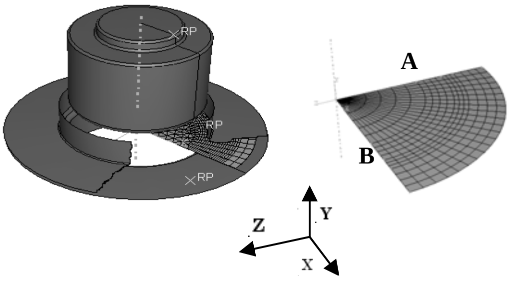


b – cylindrical part

Fig. 2. Geometry of the drawn parts.



a – rectangular part



b – cylindrical part

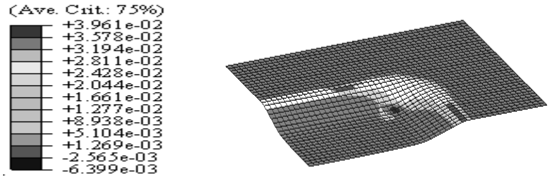
Fig. 3. Geometry of the model used in simulation.

3. INVESTIGATION RESULTS

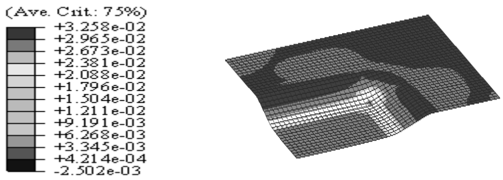
In order to determine the logarithmic strains on different zones of the part, three phases of the process were chosen: starting, middle and final, respectively.

The results of simulation for the above mentioned states of strain are presented in Figs. 4 – 7 for the rectangular and cylindrical parts, respectively.

1st phase – after drawing start

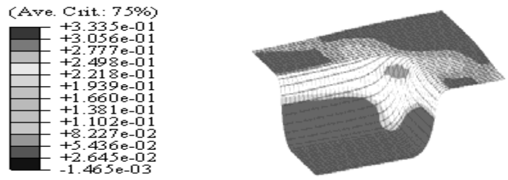


a. inner surface

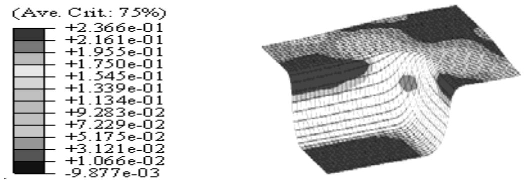


b. outer surface

2nd phase- at the drawing middle

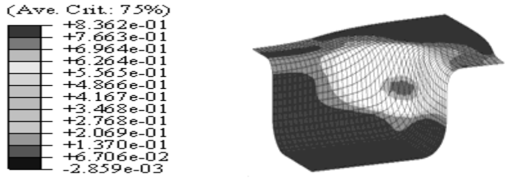


a. inner surface

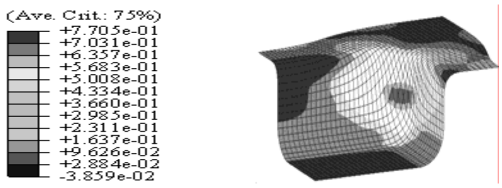


b. outer surface

3rd phase – before drawing end

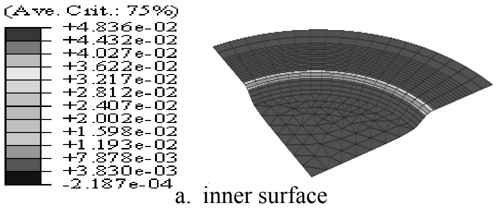


a. inner surface

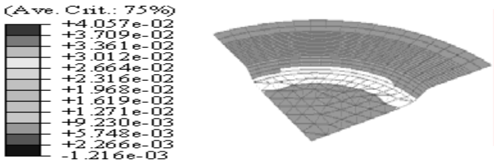


b. outer surface

Fig. 4. Strains analysis in the case of rectangular part.

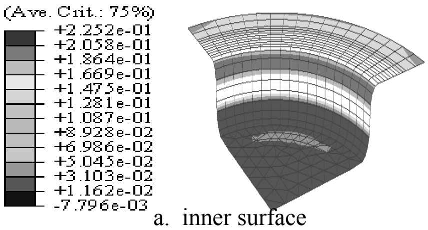


a. inner surface

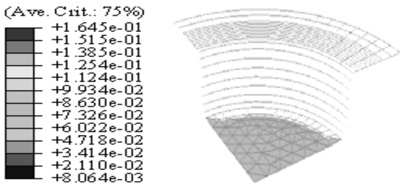


b. outer surface

2nd phase- at the drawing middle

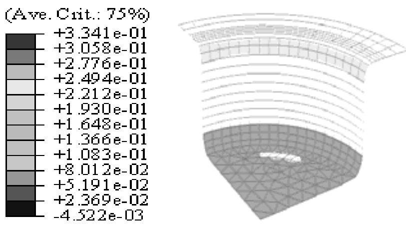


a. inner surface

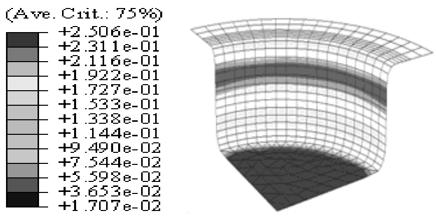


b. outer surface

3rd phase – before drawing end



a. inner surface



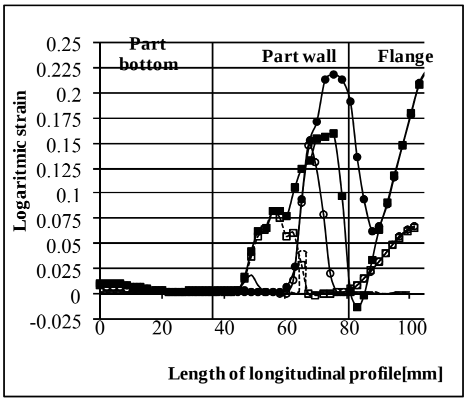
b. outer surface

Fig. 5. Strains analysis in the case of circular part.

4. CONCLUSIONS

The analysis of the state of strains on different zones and during different phases of the drawn parts leads to the following conclusions:

- in the case of rectangular parts, small differences exist between the strains from the inner and outer surfaces of the parts, the biggest being registered on the inner face; the state of strains will increase to the increase of the drawing depth; considerable increases of the strains will take place in the zones of connection between the longitudinal and transversal walls, be-



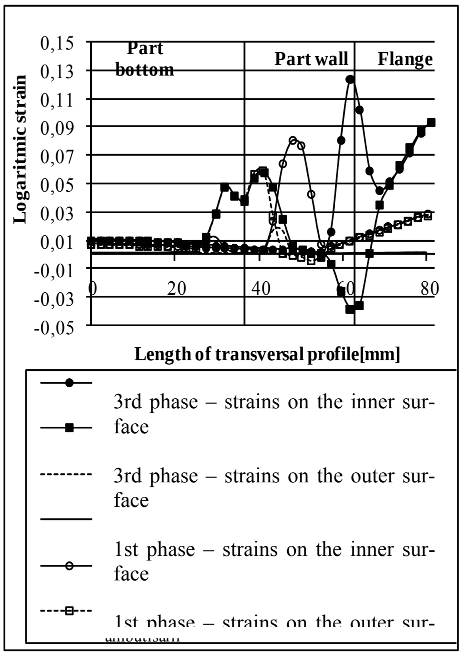


Fig. 6. Strains variation in the case of rectangular part.

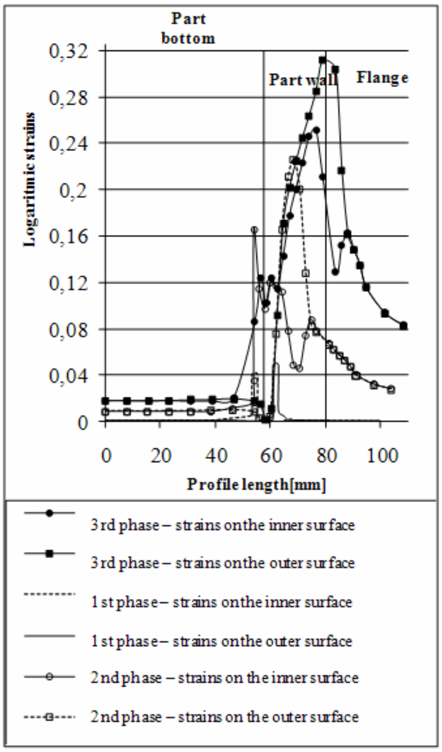


Fig. 7. Strains variation in the case of cylindrical part.

tween the part bottom with part wall and especially between the part wall with part flange;

- in the case of cylindrical parts, some differences exist between the strains from the inner and outer surfaces of the parts, the biggest being registered on the inner face; the state of strains will increase to the increase of the drawing depth; considerable increases of the strains will take place in the zones of connection between the part bottom with part wall and especially between the part wall with part flange.

From the experimental analysis concerning springback in the case of parts drawn by using different values of blankholder force [4, 5], the following aspects were remarked:

- springback lead to high values of deviations of the geometric parameters of part by comparing with the theoretical ones;
- in the zone of connection between the part wall and part bottom the springback intensity decreases when the blankholder increases;
- in the zone of connection between the part wall and part flange the springback intensity will be modified as a function of a *threshold* value of the blankholder force;
- the optimum field of variation of the blankholder force was between 25 kN ÷ 40 kN in the case of drawn rectangular parts and between 30 kN ÷ 80 kN in the case of drawn cylindrical parts.

The variation of springback parameters can be explained by the modification of the stresses and strains state of the material depending on blankholder force values. Thus, the utilization of high blankholder forces in drawing will block the flow of the material into the flange and the die cavity; the material flow blocking will lead to the elimination of the differences in the states of stress and strain between the outer and inner faces of the part, especially on the wall and will have positive consequences on the reduction of springback parameters.

The general conclusion of the present research is that, on different part zones located at different drawing depths, between the modes of material deformation and springback intensity is a tight connection. From the obtained results it can be remarked that the increase of the strains values and hence the intensification of the material deformations takes place in zones of connection between part walls and part bottom or part flange.

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