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ANALYSIS OF THE RESIDUAL STRESSES DISTRIBUTION IN THE CASE OF DRAWN PARTS MADE FROM STEEL SHEETS

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ABSTRACT
The residual stresses that occur in the machined parts after the tools removing 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. 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 different parts made from steel sheets.
Keywords: residual stress, springback, drawing process

1. INTRODUCTION
Generally, before the entrance in their servicing stage, the components of the mechanical structures contain stresses of variable sizes and senses that are generated by the processes of materials transformation (such as: mechanical machining, thermal or chemical treatments, joining etc.); that stresses are located in materials in the absence of external loads and are named residual stresses. These residual stresses combined with the stresses generated by the action of the servicing loads can have an important effect on the material or part behaviour. We can distinguish here the following two cases: the residual stresses act in an opposite sense to the loads applied on the part in its servicing stage. In this case it exists the tendency that these stresses to be reduced to zero before the increase of the combined stresses and hence to determine undesirable effects; these stresses are beneficial for the part strength (for example the fatigue strength); the residual stresses have the same sense with those determined by the servicing loads (for example the both stresses are tensile stresses). In this case, only a small load applied on the part can produce undesirable effects compared with a part with zero initial stresses. The residual stresses generated by the drawing processes are caused by the facts that between the states of the outer and inner strata of the material there are some differences and also because between the permanent deformations of the material there is an incompatibility. The presence of residual stresses in the deformed material affects its mechanical behaviour, the durability and the dimensional or shape stability of the part, the corrosion resistance of the material and its quality to be machined by different working processes. Thus, in the case of metal sheets stamping, the action of the residual stresses generated by the cold forming process influences and determines the occurrence of the springback instability phenomenon. [1,2,3,4] The knowledge of the distribution and effects of the residual stresses can bring the following beneficial advantages relating to the conception and manufacturing of the parts: to avoid the unfavourable states of residual stresses; to increase the reliability of the worked parts by decreasing the risk of their inaccuracy or premature destruction; the generation of beneficial states of residual stresses can offer the possibility to achieve some properties of the materials according to requirements imposed by a good servicing of the parts. The present paper performs an analysis based on simulation concerning the distribution of the residual stresses as

a function of different factors (blankholder force, lubrication) and of its influence on springback parameters in the case of different draw parts made from steel sheets.

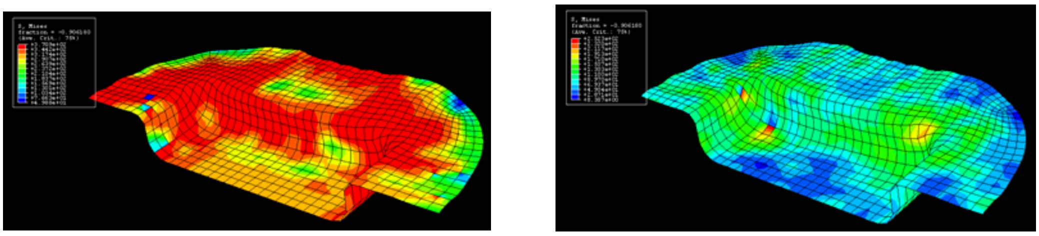
2. CONDITIONS OF RESIDUAL STRESSES SIMULATION

The analysis concerning the residual stress distribution was performed by simulation using ABAQUS-Explicit software. The 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 -12 kN.

3. INVESTIGATION RESULTS

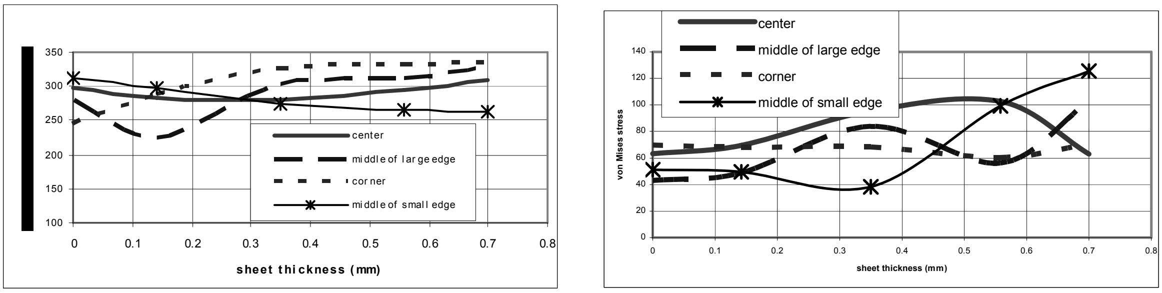
3.1 The case of rectangular parts

The results of simulation for the rectangular parts are presented in figure 1a and b - 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 figure 2.



a. after drawing *b. after springback*

Figure 1. State of stresses in the case of rectangular parts



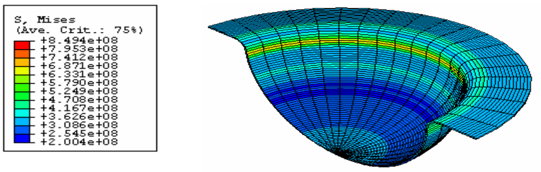
a. after drawing *b. after springback*

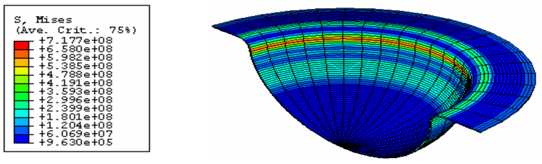
Figure 2. Distribution of the von Mises equivalent stress in the case of rectangular parts

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.

3.2 The case of hemispherical parts

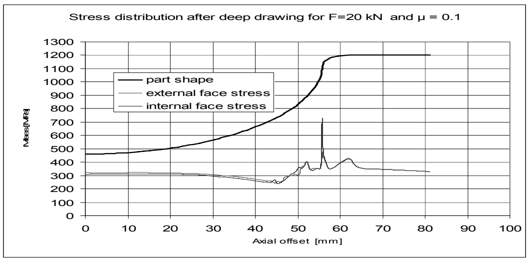
The results of simulation for the hemispherical parts are presented in figure 3a and b - for the state of stresses resulted after drawing and springback, respectively. The distributions of the von Mises equivalent stress on the sheet thickness and part bottom in the case of hemispherical part are presented in figure 4. By analysing the residual stress distribution on the all-draw part, it can be remarked an increase of the residual stress values in the region located at the zone of connection between the part body and flange.

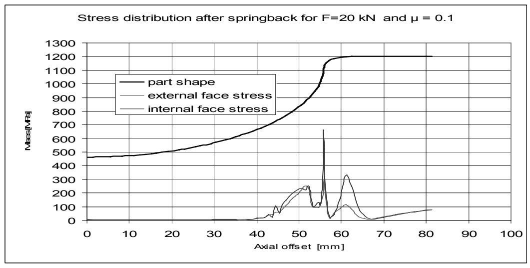




a. after drawing *b. after springback*

Figure 3. State of stresses in the case of hemispherical parts



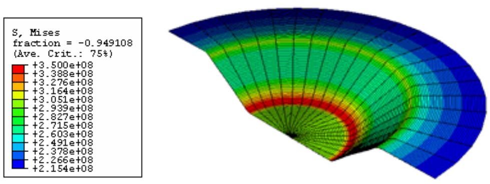


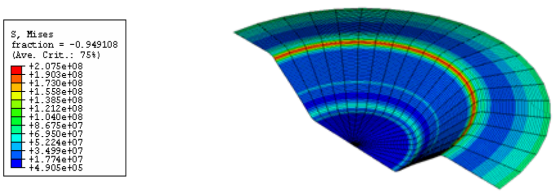
a. after drawing *b. after springback*

Figure 4. Distribution of the von Mises equivalent stress in the case of hemispherical parts

3.3 The case of conical parts

The results of simulation for the conical parts made by using a cylindrical punch are presented in figure 5a and b - 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 figure 6. In figure 7 there are presented the results of simulation for the conical parts made by using a conical punch - for the state of stresses resulted after drawing and springback, respectively.





a. after drawing *b. after springback*

Figure 5. State of stresses in the case of conical parts made by using a cylindrical punch

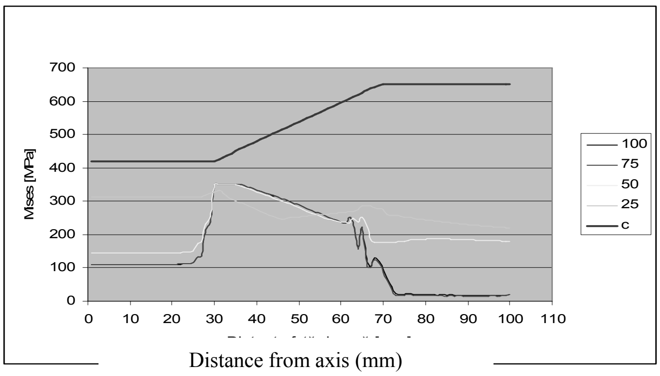
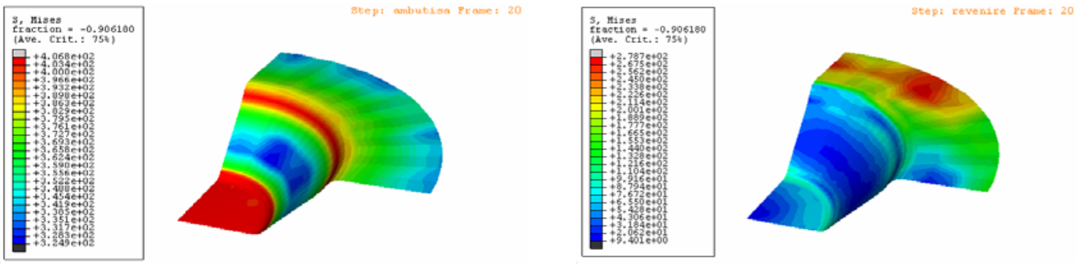


Figure 6. Distribution of the von Mises equivalent stress in the case of conical parts made by using a cylindrical punch for different blankholder forces



a. after drawing *b. after springback*

Figure 7. State of stresses in the case of conical parts made by using a conical punch

By analysing the residual stress distribution on the all-conical draw part, it can be remarked that an increase of the residual stress values was registered in the regions located at the zone of connection between the part inclined wall and 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; 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.

Acknowledgments

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