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The Influence of Numerical Parameters on the Springback Prediction of U-Shaped Part

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ABSTRACT

In the sheet metal forming process, in this case U – Bending process a deep drawing quality steel DC06 was used in the experiment. Sheet metal parts that undergo deformation exhibit springback effect, which is governed by strain recovery of material after the load removal. In this work, the numerical simulation of bending U-shaped part was performed and compared with experimental data. The springback prediction is related to many parameters like forming conditions, tool geometry and material properties such as sheet thickness, yield stress, work hardening, strain rate sensitivity, elasticity modulus and numerical parameters.

In this contribution, the deep drawing quality steel DC06 was used to study the effect of numerical parameters on the springback prediction of U- shaped part. In the numerical simulation, the yield criterion Barlat was used in combination with Ludwik hardening law. Achieved data from numerical simulation were compared with experimental test results and the impact of numerical parameters on the springback prediction was evaluated.

Keywords *– U-bending, springback prediction, simulation, numerical parameters*

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I. INTRODUCTION

Bending process is one of the most used sheet forming technologies and it represents plastic deformation of the material when the bending moment is applied. Accurate forming or bending of the steel sheets, at the design stage of process, requires taking into account specific properties of the sheet material, i.e., Young's modulus, yield stress, ratio of yield stress to ultimate tensile stress, and microstructure of the material [1].

Springback involves small strains, similar in magnitude to other elastic deformation of metals. As such, it was formerly considered a simple phenomenon relative to the large-strain deformation required for forming. Nonetheless, appreciation for the subtleties of springback in two areas has grown dramatically. In particular, high precision is needed for the large strain plastic response that directly affects the stresses in the body before removal of external forces. The unloading, while nominally linear elastic for most cases, it can show remarkable departures from an ideal linear law. [2-5]

A common countermeasure against springback is to design forming dies that anticipate springback compensation, but the compensation amount is a difficult question even for experienced die designers, and field practice is largely based on trial and error. Nowadays it is possible to use finite element analysis for more accurate prediction of springback. [5-10]

In the numerical simulation of the formation of thin sheets, shell elements are most often used, this is due to the faster calculation, which is achieved by reducing the number of degrees of freedom, compared to volume elements. The shell elements offer the possibility to represent the stresses in the direction of the sheet thickness by means of a large number of integration points (NIP). The size of the shell elements is also important factor.

Nevertheless, still in industrial practice, a very small number of integration points, typically 3 to 5, are used to simulate sheet metal forming. Some commercially available programs used to simulate forming processes do not allow the use of more than 7 to 9 points. Li et al. [11] and Wagoner et al. [12] recommend the use of 25 to 51 elements in order to achieve 99% accuracy in the prediction of the suspension compared to the actual state. Some authors of Xu et al. [13], Yao et al. [14] recommend 7 to 9 points, even Xu et al. [13] claim that if the number of integration points is higher than 7, the accuracy of the simulation decreases.

In this contribution, the influence of numerical parameters (times step t and element size e_s) on the springback prediction of U-shaped part were investigated. The yield criterion Barlat in combination with

Ludwik hardening law was used in the numerical simulation of U-bending of deep drawing quality steel. Springback data achieved from these simulations were then compared and analyzed with the experimental test results.

II. PROCESS CONDITIONS, MATERIAL PROPERTIES, GEOMETRY USED IN TESTING

In this study, springback prediction results of U – Shaped part made of deep drawing quality steel DC06 achieved with use of the numerical simulation were evaluated and compared with experimental test results. In the FE analysis it is important to input correct process, geometrical, numerical and material variables. Barlat model in combination with Ludwik hardening model was used for springback evaluation using the CAE software. Also effect of the numerical parameters on the springback prediction was evaluated. The sheet thickness of the DC06 steel was 0.85 mm. The material properties measured in rolling direction of the used steel are shown in Table 1. The forming velocity was set to 20 mm/min. for the punch. The rectangular shaped blank, which in this work had dimensions of 150 mm by 40 mm was used.

Table 1 Mechanical properties of DC06 steel

Material	Yield strength σ_y [MPa]	Tensile strength σ_u [MPa]	Young´s modulus E [GPa]	Uniform elongation A_g [%]	Strain hardening exponent n [-]	Planar anisotropy coefficient R [-]	Poisson´s ratio V [-]
DC06	148	293	210	27.9	0,261	1,724	0,3

The tool geometry is also important factor in sheet metal forming. The forming tool used in the experiment is shown in Fig. 1. Die and punch radius value was 3 mm. The forming depth was 17.5 mm. The maximum blank-holder force at the end of the punch stroke was 5.4 kN. The accuracy of the numerical simulation was set to fine. With this setting, program automatically generates mesh parameters for the tool. The triangular, shell elements were used in numerical simulations. Four different values of element size e_s: 0.8, 1.6, 3.2 and 6.4 mm were used in the numerical simulation to study the impact of element size on the springback prediction. In addition the influence of the time step was studied. Other numerical parameters were constant, such as radius penetration was set to 0.16 and number of integration points was set by software to 11. The value coefficient of friction was set to 0.27. Figure 2 shows ideal dimensions of the part a) and scheme of measurement of springback angle β b).

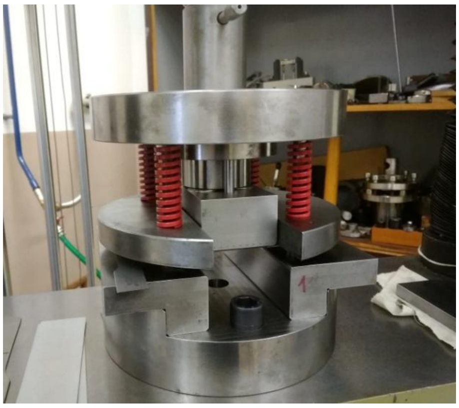

Fig. 1 Forming tool used in the experiment

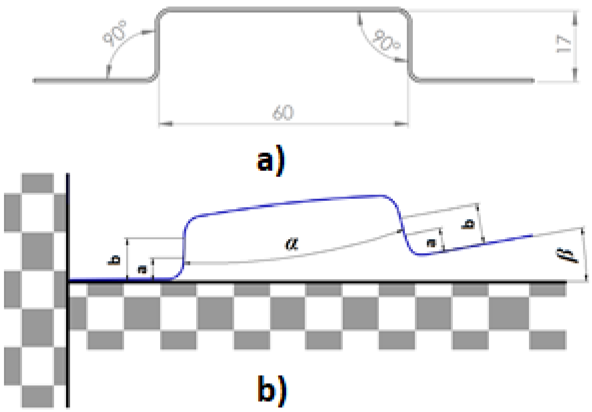

Fig. 2 Ideal part dimensions a) Springback measurement b)

III. SPRINGBACK SIMULATION, EVALUATION AND RESULTS

In this current study, finite element simulation of forming U – shaped part made of DC06 was conducted and numerical data were compared with experimental test results. For evaluation of the springback of the formed part, opening angle of arm ß [°] was measured in cross section after springback calculation. Also forming forces were attained from numerical simulation and compared with real test results. The Figure 3 shows numerical results of springback achieved with different values of element size. The Figure 4 shows impact of different values of time step on the springback prediction.

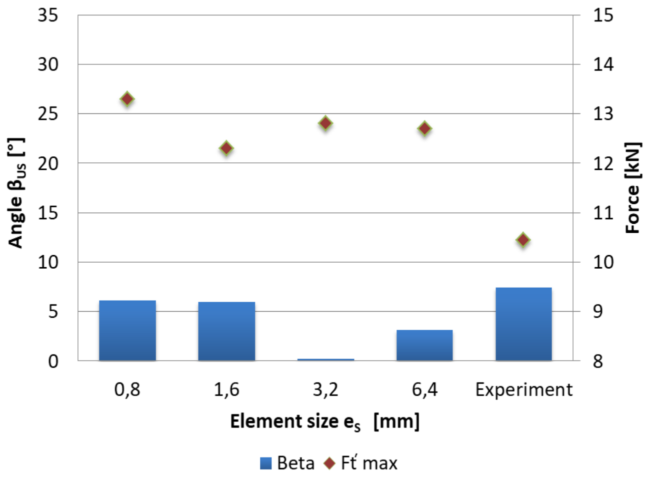

Fig. 3 Influence of element size on the springback angle ß

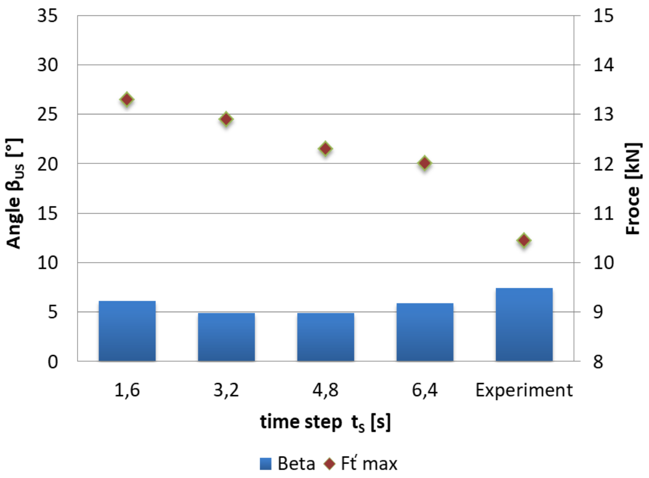

Fig. 4 Influence of time step on the springback angle ß

The predicted springback values of angle ß correlated with experimental values when lowest values of element size and time step were used in the simulation. The predicted forming force value was overestimated in all cases, but its value has decreases when higher values of time steps were used. The size of the element and value of time step also influences computing time. Thus, it is important to choose the right values of these parameters to achieve satisfactory accuracy of the springback prediction and relatively short computing time.

IV. CONCLUSION

The springback prediction of the U-shaped part made of deep drawing quality steel DC06 with use of numerical simulation shows the importance of the numerical parameters: element size and time step on the prediction results. The main reason for it might be different stress, strain values and paths which also depend on numerical parameters which can then significantly influence springback prediction. The predicted values of springback angle ß correlated with experimental results when lowest values of element size and time step were used in the numerical simulations.

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