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The Spring back Prediction of Micro-Alloyed Steel Used in V-Bending Operation

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ABSTRACT

In the sheet metal forming process, in this case micro-alloyed steel H220 exhibits springback effect, which is governed by strain recovery of material after the load removal. In this work, numerical simulation of a V-shape part bending was performed and compared with experimental data. Springback is related to many parameters like forming conditions, tool geometry and material properties such as sheet thickness, yield stress, work hardening, strain rate sensitivity and elasticity modulus.

In this contribution, the influence of process conditions on springback effect of V - shaped part made of micro-alloyed steel was investigated. In the numerical simulation, two types of Yield criterion: Hill48 and Barlat were used in combination with Swift and Ludwik hardening models. Achieved data from numerical simulation were compared with experimental test results.

Keywords –bending, springback prediction, sheet metal forming, micro-alloyed steel

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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. The importance of correct material input parameters for springback simulation is stated by numerous researchers [1].

The non-uniform strain state at the section of bent material leads to existence of residual stress after load releasing. This stress produces springback which is manifested by unintended changes in the shape of the part after the forming. The measure of the springback value can be springback coefficient or angle of springback [2].

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. [5-8]

Allowances have to be made in die design so that the final product will meet the designer's objective for both appearance and ease of assembly. Also in the sheet metal industries as automotive industries, accurate predictions of sheet metal parts including stress-strain distribution and thickness are necessary [9].

In this contribution, the influence of material criterions on the springback prediction accuracy was studied. Two types of yield criterion: Hill48 criterion and Barlat criterion were used in the numerical simulation of bending steel sheet in combination with two types of hardening laws Swift and Ludwik. 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 V – Shaped part made of deep drawing quality steel achieved with use of the numerical simulation were evaluated and compared with experimental test results. The bending experiments were conducted on hydraulic press ZD-40. This device consists of a tensometer which was used to measure applied force. The Control unit of ZD-40 collected force data, which were then transferred to PC and later processed in Excel. In the FE analysis it is important to input correct process, geometrical, numerical and material variables. Two types of yield surface models: Hill48 model and Barlat model in combination with Swift and Ludwik hardening models were used for springback evaluation using CAE software.. Sheet thickness of the used materials was 0,80 mm. Material properties of the used steel are shown in Table 1. Forming velocity was set to 1 mm/s for the punch. The rectangular shaped blank, which was used in this work had dimensions of 90 mm by 40 mm was used.

Table 1 Mechanical properties of H220 steel

Material	Yield strength σ_y [MPa]	Tensile strength σ_u [MPa]	Young´s modulus E [GPa]	Elongation at break A_{80} [%]	Strain hardening exponent n [-]	Planar anisotropy coefficient R [-]	Poisson´s ratio V [-]
H220	219	385	210	34.5	0,231	1,640	0,3

Tool geometry is also important factor in sheet metal forming. Imported CAD model of tool, used in simulation is shown in Figure 1. Bending radius on the punch was 3 mm. Bending angle was 90°. Accuracy of the numerical simulation was set to fine. With this setting, program automatically generates mesh parameters. Triangle elements were used in numerical simulations. Initial element size was set to 3 mm with max. refinement level of 2. Radius penetration was set to 0.16; number of integration points was set by software to 11. Maximum time step was set to 0.5 s and coefficient of friction value was set to 0.27.

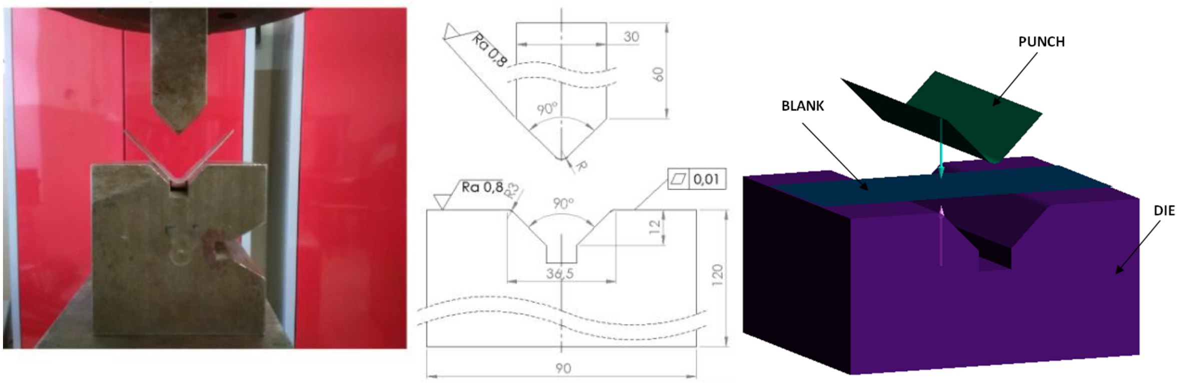

Fig. 1 Experimental tool (left), dimensions of bending tool (middle), CAD model of the bending tool (right)

III. EXPERIMENT, SIMULATION, EVALUATION AND RESULTS

In this current study, finite element simulation of forming V – shaped part made of H220 steel 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 with use of both yield criterions and both hardening models. Also influence of forces on springback, which were achieved from numerical simulation, was compared with real test results. Figure 2 shows bending force measured during V-bend testing using punch with radius of 3 mm.

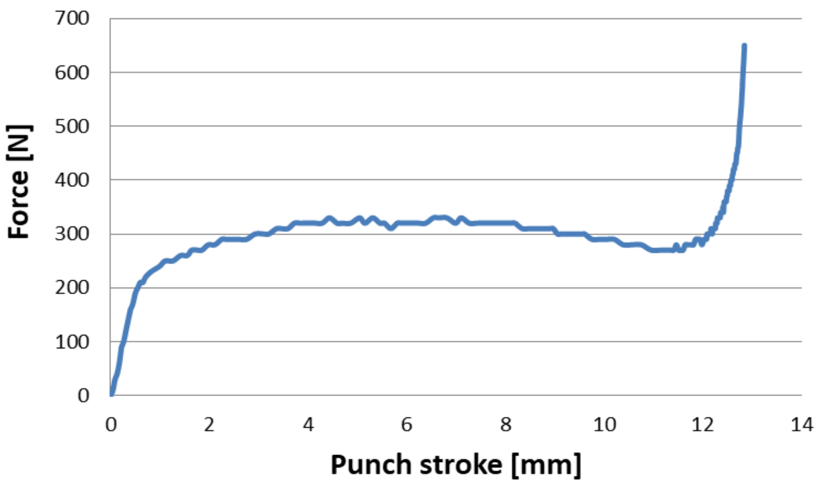

Fig. 2 Force measured during V-bending of H220 steel – bending with calibration force F=650 N

Figure 3 shows graph with obtained values of predicted springback and experimentally measured value of Arm opening angle β of the formed H220 steel. In the numerical prediction 4 combinations of different yield locus models and hardening laws were used. Based on these results, it can be stated that Barlat yield surface model in combination with Ludwik hardening law showed good correlation with experimental results. The lowest accuracy of the springback prediction was achieved using the Hill yield surface model in combination with the Swift hardening law. Table 2 shows data regarding forces and computing time achieved in numerical simulations. Barlat Ludwik material model showed good correlation with the experimental calibration force value. The shortest computing time was achieved using Hill Ludwik material model in the numerical simulation.

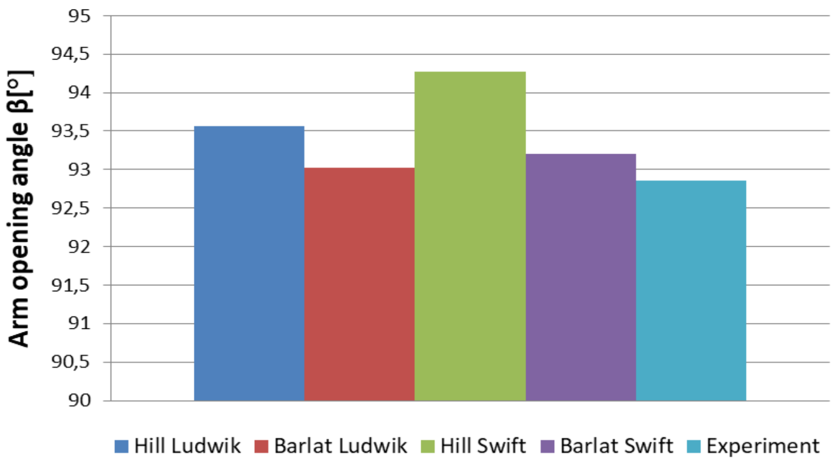

Fig. 3 Comparison of predicted and experimental Arm opening angle ß

Table 2 Comparison of predicted and experimental forces in V – bending of H220 steel, simulation computing time comparison

	Bending force [N]	Calibration force [N]	Computing time [s]
Experiment	330	650	x
Hill Ludwik	404	642	26.47
Barlat Ludwik	365	655	26.70
Hill Swift	440	669	26.56
Barlat Swift	321	678	26.68

IV. CONCLUSION

Springback prediction of the V-shaped part, made of micro-alloyed steel H220 with use of numerical simulation shows that for both Yield criterions used in simulation: Hill48 and Barlat show higher values of opening angle ß than the experimental test results in all cases. The main reason for it might be different stress, strain values and paths which depend on material model inputs that can significantly influence springback prediction. Barlat Ludwik material model used in simulation achieved good correlation with the experimental test results regarding Arm opening angle β, the difference between measured and predicted angle was less than 0.3 degrees.

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