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The comparison of springback of different steels used in the bending process

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--**ABSTRACT**--
In the sheet metal forming process, in this case V – Bending process two types of steels were used in the experiment, deep drawing quality steel DC06 and high-strength steel with TRIP effect RAK40/70 exhibit springback effect, which is governed by strain recovery of material after the load removal. In this work, the numerical simulation of bending V-shape part 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 parts made of deep drawing quality steel DC06 and TRIP steel RAK40/70 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** – V bending, springback prediction, trip steel, drawing quality steel, process conditions*

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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. [5-8]

The TRIP steels, or Transformed Induced Plasticity steels, have higher values of mechanical properties (yield strength and tensile strength) if compared with conventional steels. Strain hardening is also greater, therefore they offer a superior combination of strength and formability properties which can be contributed to multiphase structure of these steels. The main characteristic of TRIP steels is that they modify the microstructure during the plastic deformation process as part of the austenite transformation to martensite, with the following change of the material properties. One of the main issues of TRIP steels is strong elastic recovery, also known as springback, which occurs after forming. [9]

In this contribution, the influence of process conditions (tool radius R and bending, calibration force F) on springback effect and its prediction of V-shaped part were investigated. Two types of Yield criterion: Hill48 criterion and Barlat criterion were used in the numerical simulation of bending two different types of the steel sheets. 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 V – Shaped part made of deep drawing quality steel DC06 and high strength steel RAK 40/70 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. Two types of yield surface models: Hill48 model and Barlat model in combination with Swift and Ludwik hardening model were used for springback evaluation using CAE software. Also effect of bending radius R and calibration force F on springback was evaluated. Sheet thickness of the DC06 was 0,85 mm and RAK 40/70 had thickness of 0,75 mm. Material properties of the used steels 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 DC06 steel and RAK40/70 steel

Material	Yield strength σ_y [MPa]	Tensile strength σ_u [MPa]	Young´s modulus E [GPa]	Uniform elongation A_g [%]	Strain hardenin g exponent n [-]	Planar anisotropy coefficient R [-]	Poisson´s ratio V [-]
DC06	148	293	210	27.9	0,261	1,724	0,3
RAK40/70	441	766	210	24,7	0,293	0.680	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. Two different values of bending radius were used in experimental work: 1 mm and 3 mm radius. 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. Figure 2 shows scheme of measurement of springback angle β.

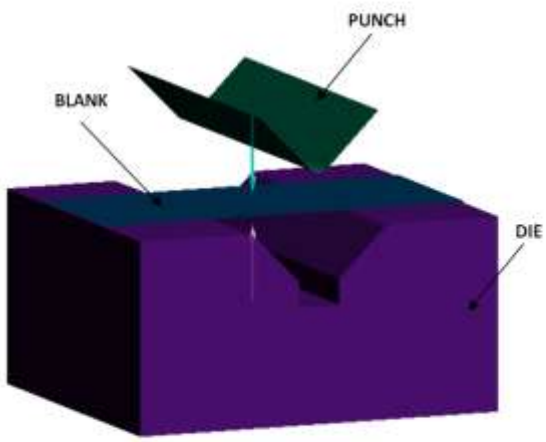

Fig. 1 CAD model of the bending tool

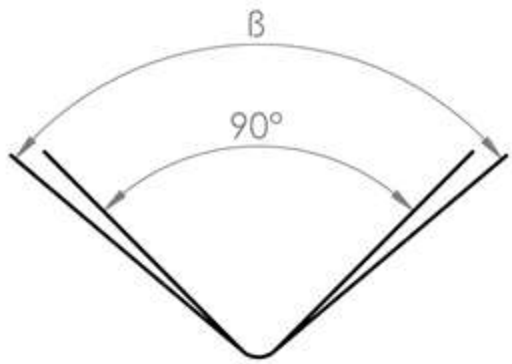

Fig. 2 Measurement of springback angle β [°]

III. SPRINGBACK SIMULATION, EVALUATION AND RESULTS

In this current study, finite element simulation of forming V – shaped part made of DC06 and RAK 40/70 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 3 shows experimental results of measured springback after V-bending process using two sets of punches with radius of 1 mm and 3 mm.

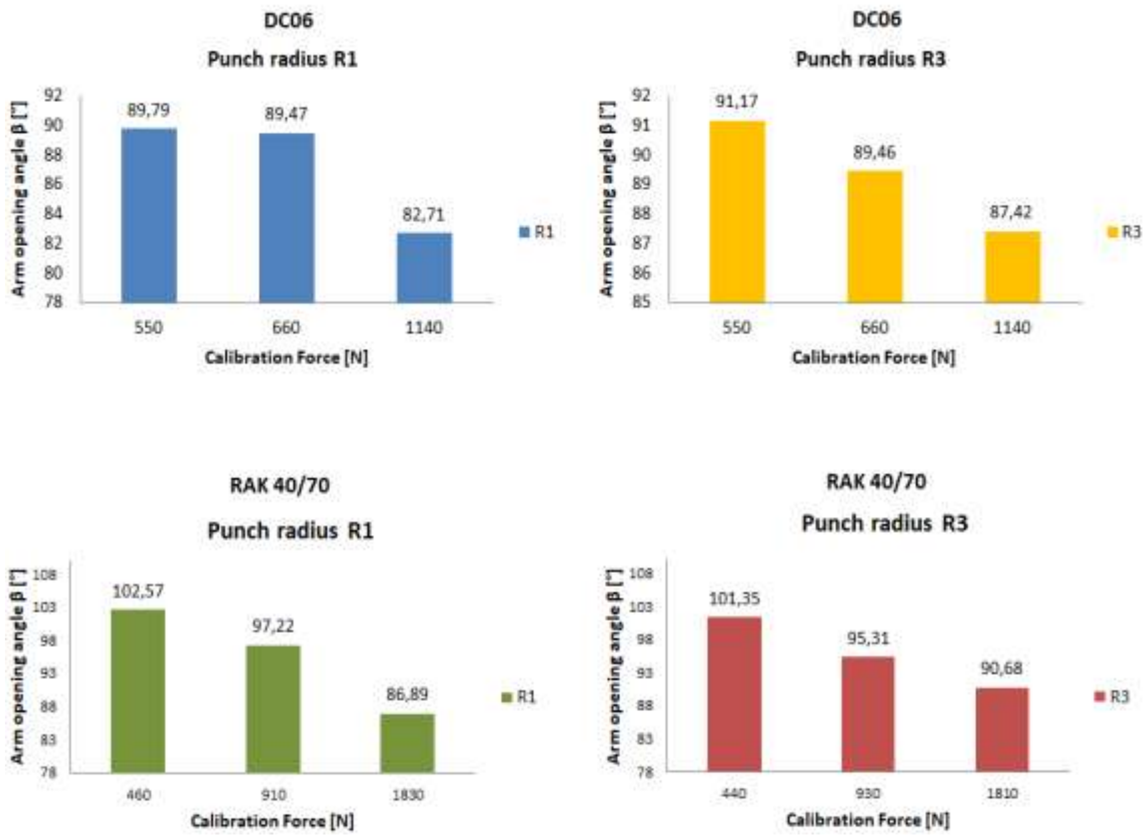

Fig. 3 Experimental results of measured springback after V-bending process

When the punch with smaller radius was used, then measured values of springback were lower in comparison with punch of 3 mm radius as seen in fig. 3. It is probably because of higher plastic deformation occurrence when 1 mm punch radius was used. Also the higher the calibration force was used; the lower arm opening angle ß was measured. The lowest force represents bending without calibration. Curious phenomenon happened when the highest value of calibration force was applied. In most cases the springback angle was lower than the angle of the die/punch. In addition, the DC06 showed much lower values of springback angle β than TRIP steel RAK 40/70. It is because of the much higher value of yield strength Re in the case of TRIP steel.

Figure 4 shows graph with obtained values of springback – arm opening angle ß of the formed DC06 steel. These values were obtained from the numerical simulation. Different values of springback achieved in experimental testing process and in numerical simulations are also shown in this picture. In figure 5 springback values obtained from numerical simulations for TRIP steel RAK 40/70 are presented. In most cases, numerical simulation predicted higher value of springback angle than the experimentally measured values.

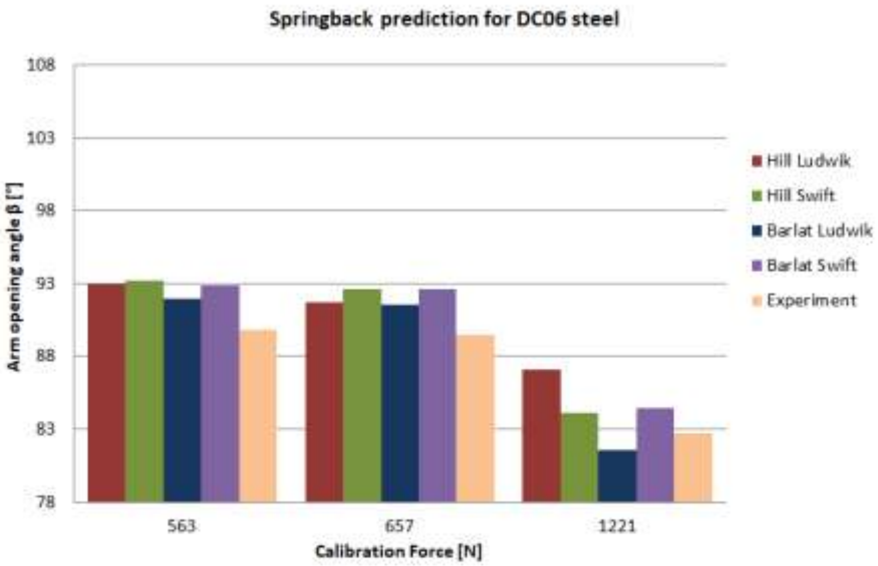

Fig. 4 Graph showing values of opening angle ß [°] and bending (calibration) force F [N] for deep drawing quality steel DC06, punch radius R=1 mm

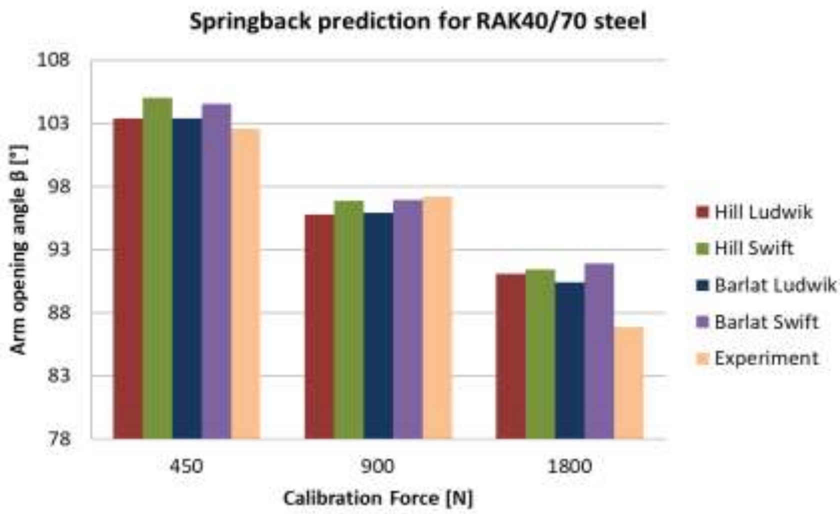

Fig. 5 Graph showing values of opening angle ß [°] and bending (calibration) force F [N] for high strength steel RAK 40/70, punch radius R=1 mm

IV. CONCLUSION

Springback prediction of the V-shaped parts, made of deep drawing quality steel DC06 and TRIP steel RAK 40/70 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 most cases. The main reason for it might be different stress, strain values and paths which depend on material model inputs, which can then significantly influence springback prediction. Punch radius also affects springback values, it can be said that, the smaller the punch radius is used, the lower values of opening angle ß will be obtained. Also the TRIP steel shows higher values of springback in comparison with deep drawing quality steel DC06.

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