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Tool design as springback reduction measure of U-shaped part

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ABSTRACT

The springback of sheet metal parts is negative effect which occurs after the forming operation. These parts undergo deformation, which consists of elastic and plastic deformation. The springback effect is related to elastic deformation, which is governed by strain recovery of material after the load removal. 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 work, the influence of tool design on the springback effect of formed part is evaluated.

In this contribution, the TRIP steel RAK40/70 was used to study the effect of tool design on the springback reduction of U-shaped part. To verify the test results, numerical simulations were conducted. In the numerical simulation, the yield criterion Hill48 was used in combination with Ludwik hardening law. Achieved data from numerical simulation were compared with experimental test results and the impact of tool design on the springback reduction was evaluated.

Keywords *– U-bending, tool design, springback prediction, springback reduction*

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I. INTRODUCTION

High-strength steels have been used in the automotive industry for over three decades. The use of these steels can reduce the weight of the car as well as increase passive safety. Reducing the car's weight improves fuel economy, resulting in lower CO2 emissions. The main disadvantages of the high-strength steels compared to conventional drawing steels are worse formability and greater springback effect. The most common measure against the springback of the stamped parts is to design the forming tool in such a way that its geometry compensates for the springback.

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. [2]

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]

Lawanwong et al. [11] proposed a novel technology called "double-action bending" to eliminate springback of the stamped part made of advanced high-strength steel. They used FE analysis to determine process and tool parameters before the experiment try-out. Slota et al. [12] performed a numerical and experimental study in which the impact of the process parameters on the springback was studied. They found that higher values of blankholder force in combination with greater friction coefficient decrease the amount of springback of the hat-shaped part. Cui et al. [13] proposed a new stamping method for forming the L-shaped part. They call this method an electromagnetic-assisted stamping (EMAS). They used a magnetic force to control the springback phenomenon. The results showed that as discharge voltage increases, the bent angle after springback decreases. Therefore, research related to the springback phenomenon which is oriented on process parameters can significantly help with the reduction or elimination of the springback which appears after the forming process.

In this contribution, the influence of tool design on the springback of U-shaped part was investigated. The yield criterion Hill48 in combination with Ludwik hardening law was used in the numerical simulation of

U-bending of TRIP steel. Springback data achieved from these simulations were then compared and analyzed with the experimental test results.

II. PROCESS CONDITIONS, MATERIAL PROPERTIES AND TOOL DESIGN

In this study, effect of tool design on springback reduction was studied and springback prediction results of U – Shaped part made of TRIP 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. The Hill48 model in combination with Ludwik hardening model was used for springback evaluation using the CAE software. The sheet thickness of the RAK 40/70 steel was 0.75 mm. The material properties measured in rolling direction of the used steel are shown in Table 1. In the U-bending experiment, the forming velocity was set to 20 mm/min. for the punch. The forming depth was 16.5 mm. The rectangular shaped blank, which in this work had dimensions of 150 mm by 40 mm was used.

Table 1 Mechanical properties of RAK 40/70 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 [-]
RAK 40/70	440	766	210	27.9	0.293	0.804	0,3

The tool geometry is also important factor in sheet metal forming. The two types of forming tools used in the experiment are shown in Fig. 1. The conventional tool design consisted of punch, die and blank holder Fig. 1a. The innovative tool design consisted of the same parts with the addition of counter punch Fig. 1b. Die and punch radius value was 3 mm. The forming depth was 16.5 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. The element size e_s: 0.8 was used in the numerical simulation. The value of time of step was t_s= 1.6 s. 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).

a) b)

Fig. 1 Forming tools used in the experiment : conventional tool a), innovative tool with counter punch b)

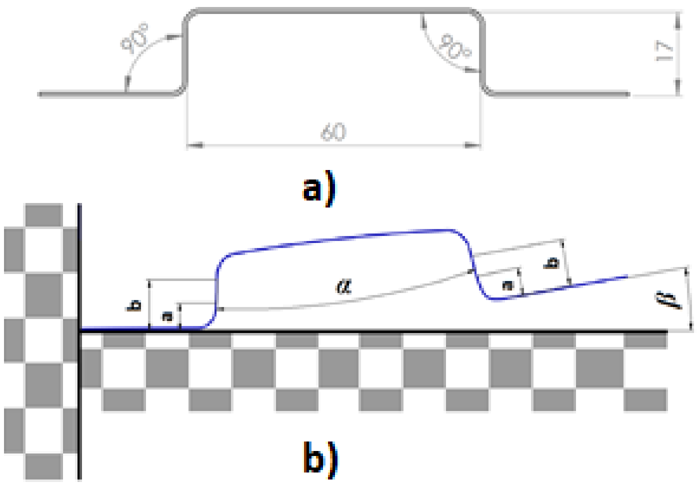

Fig. 2 Ideal part dimensions a) Springback measurement b)

III. EXPERIMENTAL AND SIMULATION RESULTS

In this current study, the influence of tool design of the springback of U – shaped part made of RAK 40/70 steel was studied. Experimental results were compared with simulation results and evaluated. 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 measured for both tools Fig. 3. The results of measured and predicted springback angles are shown in Tab. 2.

Springback angle	**Conventional tool T_C [°]**	**Conventional tool prediction T_{CP} [°]**	**Innovative tool T_I [°]**	**Innovative tool prediction T_{IP} [°]**
Arm opening angle **ß**	33.1	17.8	22.8	19.4
Part opening angle **α**	28.8	23.4	17.5	21.2

IV. CONCLUSION

The springback prediction accuracy and springback reduction are the most challenging problems in forming processes. In the presented article, the influence of tool/process design on the springback of U-shaped part was investigated. The innovative tool with counterpunch showed lower values of springback angles. The reason for it is greater plastic deformation of the material when counterpunch was used. With the increase of plastic deformation, the impact of elastic deformation is less prominent, thus reducing the springback of the formed part. Based on the experimental and numerical results, the following outputs can be stated:

- Significant reduction in values of springback angles α (reduction of 39%) and β (reduction of 32%) was achieved with the use of the tool design which includes counterpunch.
- This tool design can be adopted for stamping hat-shaped parts in industrial practice.
- The springback prediction of the hat-shaped part was less accurate, than anticipated. The reason for it can be explained by the use of isotropic hardening model.

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