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Springback prediction in sheet metal forming via FEA simulation

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ABSTRACT

Improved passive safety and weight reduction are both required for components of new car generation. Thus, advanced high strength steels, such as dual phase steels are increasingly used in car-body production. In each sheet metal forming process, the steels exhibit springback effect, which is governed by strain recovery of material after load removal. High strength steels exhibit more distinct springback effect than steels used for deep drawing. This is mainly due to their higher values of Yield strength. 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. [1-3]

In this contribution, effect of blank holder force (BHF) value and value of friction coefficient on springback of stamped part is evaluated. Two materials – double phase steel DP600 and cold rolled low carbon steel used for cold forming DC04 in FEA simulation of the sheet metal forming process were investigated.

Keywords: *springback, sheet metal forming, FEA forming simulation*

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I. INTRODUCTION

The automotive industry is facing challenges of reducing body weight in consideration of environmental problems and higher collision safety; as a solution for both these factors, use of higher strength steels for car bodies is expanding. [4] Developed high-strength steels have different strength levels to give a wide selection of steels for different applications according to the required task. Compared with other light-weight materials, high strength steels have advantages in terms of expenses, availability of production facilities, etc., and as such, they are widely used material for improvement of body weight reduction and collision safety. Usage of higher-steel strength leads to forming problems: low elongation consequent to higher strength increases the risk of sheet breakage during sheet forming, and a higher yield stress causes dimensional defects (springback), wrinkles, and other troubles. [1]

Springback in the present refers to the change of shape which is elastically driven. Springback occurs following a sheet forming operation when the forming loads are removed from the work piece – sheet metal. It is usually undesirable, causing problems in the next forming operations, in assembly, and in the final product. These problems typically degrade the accuracy, appearance and quality of the products being manufactured. [3]

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. [5-7]

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. [8, 9]

The aim of this work was to investigate effects of blank holder force (BHF) values and values of friction coefficient on the springback of stamped part by means of FE modeling. Double phase steel DP600 and cold rolled low carbon steel DC04 in FEA simulation of the sheet metal forming process were investigated. Mechanical properties of the investigated steels were obtained from the material library of the FEA simulation software. Values of selected material properties are shown in the Table 1.

Table 1 Mechanical properties of selected steels

Material	Yield strength σ_y [MPa]	Tensile strength σ_u [MPa]	Strain hardening exponent n [-]	Planar anisotropy coefficient R [-]	Poisson´s ratio V [-]
DC04	167,9	303,5	0,211	1,650	0,3
DP600	351,0	659,8	0,209	0,975	0,3

II. HILL – 48 MATERIAL MODEL

The springback effect can be defined as the elastic recovery of the material. In this work Hill´s material model was used. The yield surface determines the conditions for material flow in terms of stress components (Fig.1). The yield surface is assumed to be quadratic function (elliptic function) which is defined by the three r values $\mathbf{r_0}$, $\mathbf{r_{45}}$, $\mathbf{r_{90}}$ and the initial yield stress.

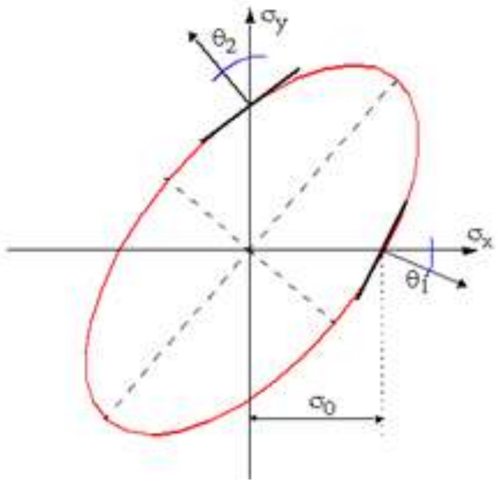

Fig. 1 Yield surface for the Hill-48 model

In the yield surface for rolling directions, and the perpendicular directions with respect to the rolling directions, are represented in the main stress directions, the two angles σ_1 and σ_2 are determined using the r values $\mathbf{r_0}$ and $\mathbf{r_{90}}$.

One of the most common yield criteria that is used in the FEA simulation of forming processes is Hill-48 quadratic yield function which is given as follow [10].

$$2f(\sigma_{ij}) = F(\sigma_y - \sigma_z)^2 + G(\sigma_z - \sigma_x) + H(\sigma_x - \sigma_y) + 2L\tau_{yz}^2 + 2M\tau_{zx}^2 + 2N\tau_{xy}^2 = 1 \tag{1}$$

Where x, y and z are orthogonal axes of orthotropy. F, G, H, L, M and N are the material constants. Hill-48 quadratic yield function, under plane stress condition, can be written in the following form:

$$2f(\sigma_{ij}) = (G + H)\sigma_x^2 - 2H\sigma_x\sigma_y + (H + F)\sigma_y^2 + 2N\tau_{xy}^2 = 1 \tag{2}$$

In equation (2), F, G, H and N parameters can also be written in terms of the anisotropy parameters r_0, r_{45} and r_{90}.

$$F = \frac{r_0}{r_{90}(1+r_{90})},\ G = \frac{1}{(1+r_0)},\ H = \frac{r_0}{(1+r_0)},\ N = \frac{(r_0+r_{90})(1+2r_{45})}{2r_{90}(1+r_{90})} \tag{3}$$

III. SPRINGBACK PREDICTION VIA FEA SIMULATION

In this current study, finite element simulation of forming sheet metal part (Fig.2a) was performed. Initial blank thickness was 1 mm for both tested steels. Radius used for punch was 5 mm; radius of die was 8 mm. Punch velocity was set to 1 mm/s. Accuracy of the numerical simulation was set to fine. With this setting, program automatically generates mesh parameters. For evaluation of the springback of the stamped part two sections in this part (section A and section B) were selected (Fig.2b). In these sections, geometry of stamped part before and after springback numerical simulation was compared.

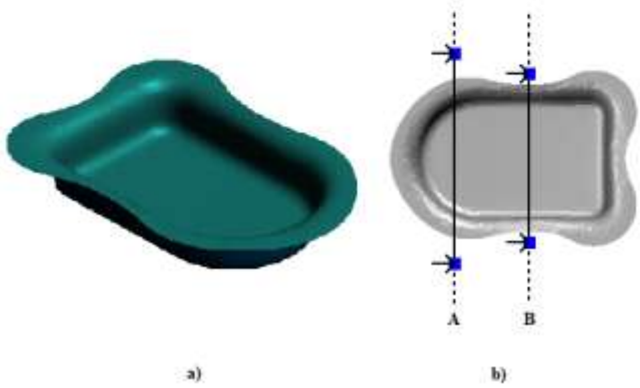

Fig. 2 Formed part obtained from the process simulation (a), two sections in the part for springback evaluation (b)

Figure 3 shows graphs with obtained values of springback angle of the material under blank holder in section A, different values of blank holding force and friction coefficient were used for both tested steels – DC04 and DP600. These graphs show that springback angle was in most cases higher for DP600 steel. DC04 showed higher value of springback angle only when BHF was set to 15 kN and friction coefficient *f* was set to 0.15. Higher values of blank holding force showed smaller values of springback angle in most cases.

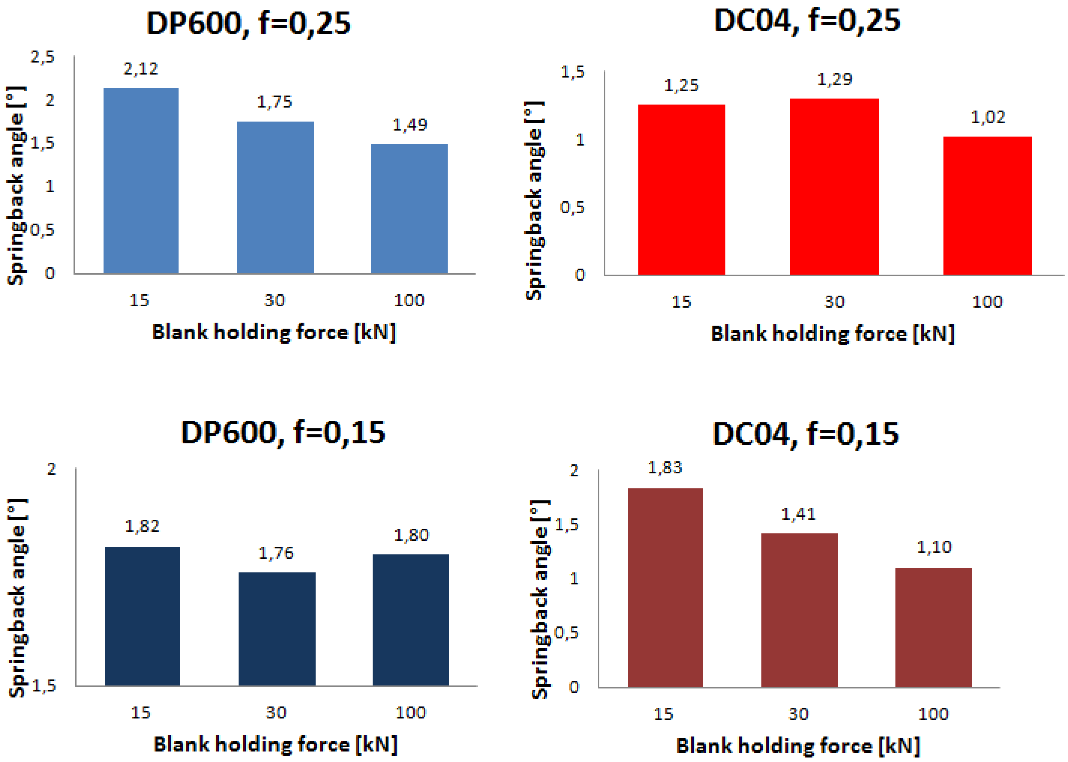

Fig. 3 Graphs showing springback angle for different values of BHF [kN] and friction coefficient *f* [-]

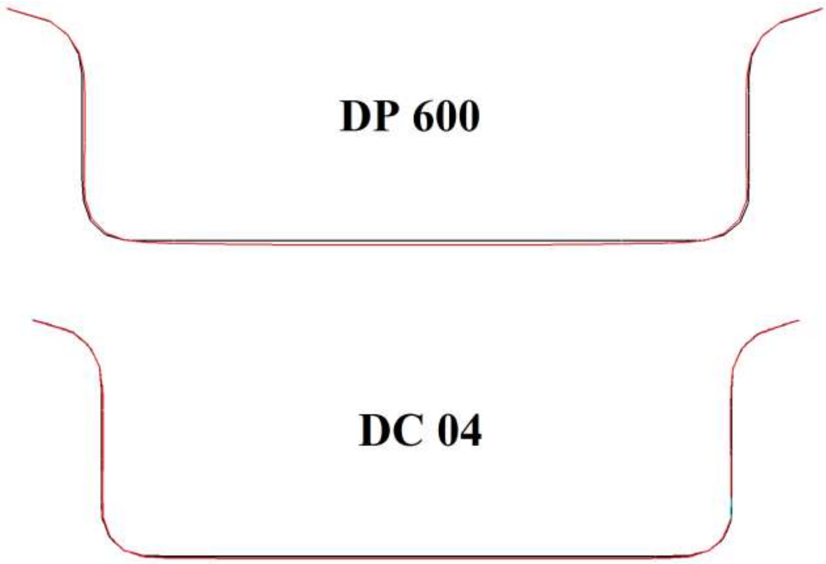

Fig. 4 Comparison of springback of the part made of the DP 600 and DC 04 steel in the section B, value of the blank holder force was 15 kN, value of coefficient of friction was 0,15

IV. CONCLUSION

Springback of the part, made of DP600 steel was greater in comparison with low carbon steel DC04 (Fig. 4). Springback effect was greater in the section B than in the section A. The main reason for it may be the lower stress values in the section B. Three values of BHF were tested – 15 kN, 30 kN and 100 kN in the forming simulation of the part. Change of the BHF from minimal to maximal value had effect on the springback of the part. In most cases higher BHF had positive effect on reducing springback angle. For example springback angle of DP600 steel was reduced by 30 %. It was done by increasing BHF from 15 kN to 100 kN Change of coefficient of friction from 0.15 to 0.25 also had positive effect on reducing springback angle.

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