The International Journal of Engineering and Science (IJES)
|| Volume || 6 || Issue || 12 || Pages || PP 62-67 || 2017 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Influence of forming method and process conditions on springback effect in the sheet metal forming simulation

Peter Mulidrán[1], Emil Spišák[1], Janka Majerníková[1], Tomáš Sleziak[1], Miroslav Greš[1]

[1]*Department of Mechanical Technologies and Materials, Faculty of Mechanical Engineering, Technical University of Košice, Košice, Slovakia*
Email: peter.mulidran@tuke.sk, janka.majernikova@tuke.sk, emil.spisak@tuke.sk

--ABSTRACT--
Springback prediction is necessary when applying high-strength steel sheets to automotive parts. The accuracy of springback prediction depends on the material model, which describes the deformation behavior of steel sheets. In each sheet metal forming process, the steels exhibit springback effect, which is governed by strain recovery of material after load removal. Considering springback occurred in a formed part is significant for designing tools and dies. In this work, numerical simulation of a U-shape forming test were performed and compared for investigating the springback effect. Two steels with different strengths were taken into account. 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.
In this contribution, effect of used forming method and process conditions on springback of U - shaped part is evaluated. Two materials – double phase steel DP600 and mild steel DC04 were investigated.

Keywords: *springback prediction, sheet metal forming, numerical simulation, high strength steels*

Date of Submission: 15-11-2017 Date of Publication: 05-12-2017

I. INTRODUCTION

In order to reduce the fuel consumption of automobiles, the use of lightweight materials, such as advanced high-strength steels (AHSS), has been progressively adopted in the automotive industry [1-3]. However, these materials present low formability, resulting from the higher values of yield stress and lower elongation compared to conventional steels. Furthermore, the AHSS are more susceptible to non-traditional behaviour, among which springback, wrinkling and fracture (or necking) are the main failure modes in sheet metal forming. [2]
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. [4-7] 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. [5-9]
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. [9-12]
Springback phenomenon is influenced by process conditions (friction coefficient, forming speed, etc.), geometry (punch, die, blank geometry, etc.), used material (Yield Strength, anisotropy, strain, hardening, etc.) and numerical variables (type, size and number of elements, yield surface model, hardening model, etc.). These variables are shown in the Fig. 1.

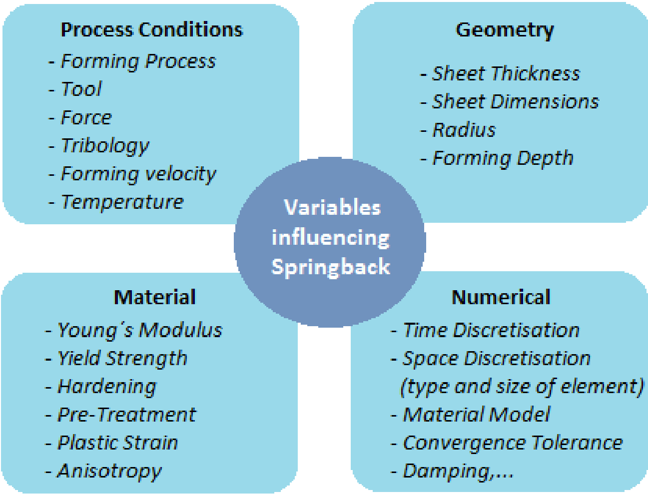


Fig. 1 Variables influencing Springback

The aim of this work was to investigate effects of used forming method, blank holder force (BHF) values, pressure pad values and values of friction coefficient on the springback effect of U- shaped part by means of finite element analysis. Used tools in numerical forming simulation of U- shaped part are shown in Fig. 1. Mild steel DC04 and double phase steel DP 600 were used in the sheet metal forming simulation. Mechanical properties of the investigated steels were obtained from the material library of the FEA simulation software.

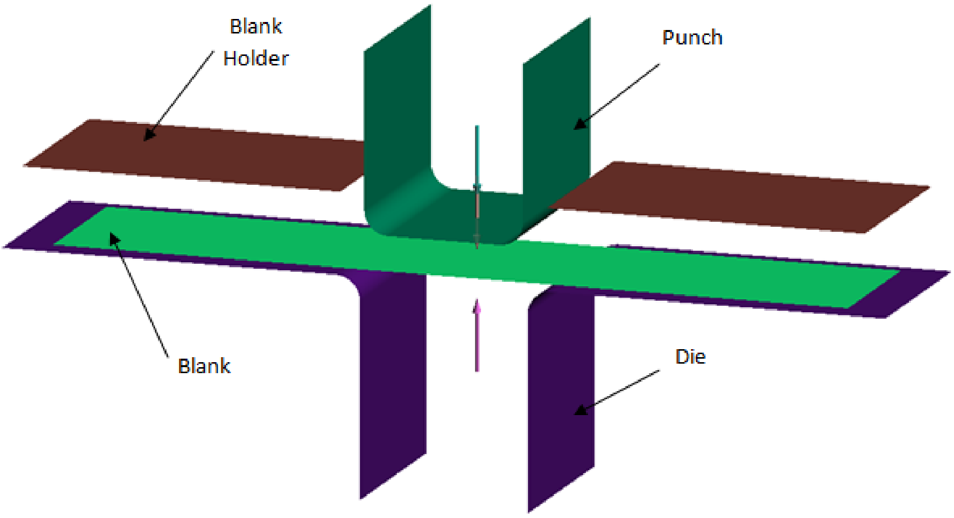
II. PROCESS CONDITIONS, MATERIAL PROPERTIES, GEOMETRY USED IN SIMULATION

In this contribution springback effect of U – Shaped part is evaluated in FEA simulation. In FE analysis it is important to input process, geometry, numerical and material variables. Variables in forming process were Blank holding pressure, pad pressure and coefficient of friction (Tab.1). Two steels - DC04 and DP600 were examined for springback using CAE software. Sheet thickness for both materials was 1 mm. Material properties of these steels are shown in Table 2. Forming velocity was set to 1 mm/s for the punch of both tools. Rectangular shaped blank which dimensions are 200 mm by 40 mm used for both tools is shown in Fig. 2.

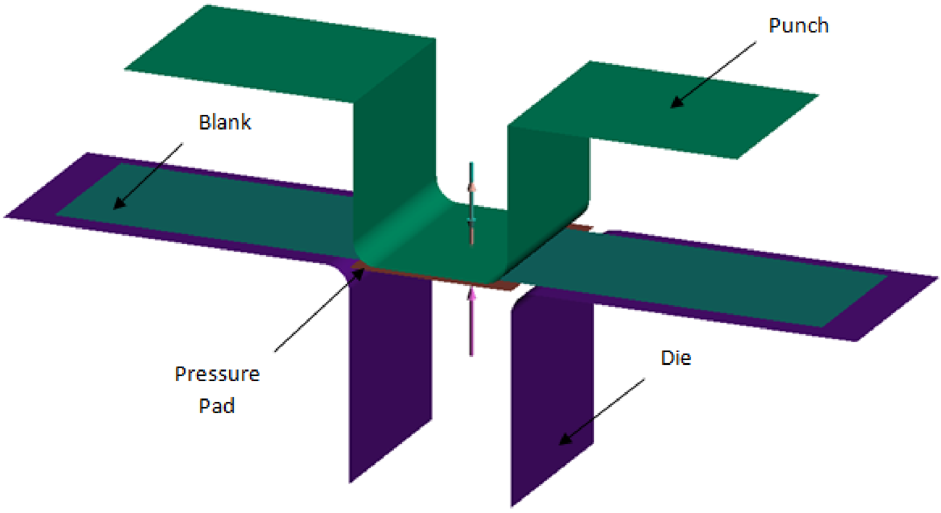
Table 1 Variables in forming process of U – shaped part

Tool	Coefficient of friction no. 1 [-]	Coefficient of friction no. 2 [-]	Blank holding pressure no.1 [MPa]	Blank holding pressure no.2 [MPa]	Pad pressure no.1 [MPa]	Pad pressure no. 2 [MPa]
With blank holder (a)	0,15	0,25	1,8	2,8	x	x
With pressure pad (b)	0,15	0,25	x	x	1,8	2,8

Tool geometry is also important factor in sheet metal forming. Imported CAD models of tools, used in simulation are also shown in Figure 2. Radius used for punch and die was 6 mm. Forming depth was set to 40 mm. Width of the U- shaped part was 40 mm. Forming clearance was 1,2 mm in both forming tools. Accuracy of the numerical simulation was set to fine. With this setting, program automatically generates mesh parameters. Triangle elements were used in simulation. Initial element size was set to 2 mm with max. refinement level of 1. Radius penetration was set to 0.16; number of integration points was set by software to 11.



a) Bending tool with blank holder



b) Bending tool with pressure pad

Fig. 2 Tools used in numerical simulation of forming process

Table 2 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

III. SPRINGBACK SIMULATION OF U – SHAPED PART

In this current study, finite element simulation of forming U – shaped sheet metal part (Fig.3) was conducted. The Fig. 3 shows part formed in bending tool with blank holder a) before and b) after springback calculation, material used in simulation was DP600 steel. Blank holder pressure was set to 1,8 MPa, value of coefficient of friction *f* was 0,15.

For evaluation of the springback of the stamped part, opening angle of arm ß [°] and sidewall curvature *R* [mm] in cross section was measured after springback calculation.

Fig. 3 Formed part before springback calculation (a), formed part after springback calculation (b)

Figure 4 shows graphs with obtained values of springback, opening angle ß of the material for a) tool with blank holder and b) tool with pressure pad. Different values of blank holding pressure, pad pressure and friction coefficient were used for both tested steels – DC04 and DP600. These graphs show that springback, opening angle was in all cases higher for DP600 steel. Tool with blank holder (tool a) shows lower values of springback than tool with pressure pad (tool b). Higher coefficient of friction has positive effect on opening angle of arm, it lowers springback angle.

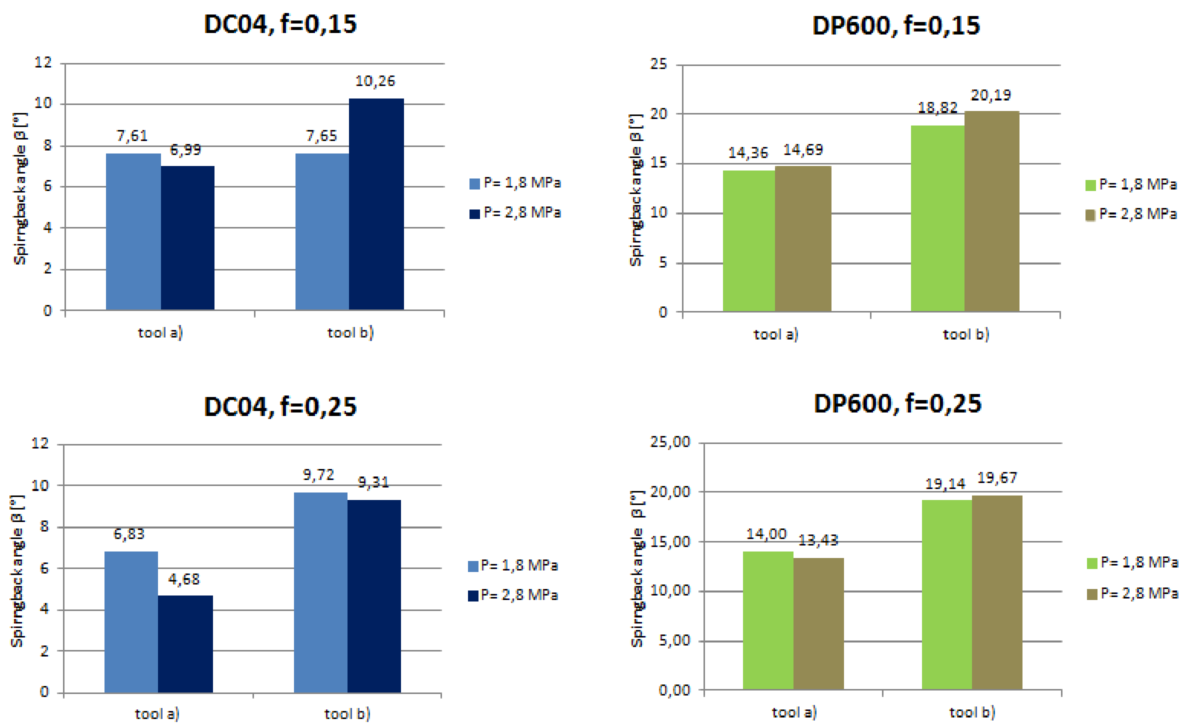


Fig. 4 Graphs showing opening angle for both steels with different values of pressure [MPa] and friction coefficient *f* [-]

Figure 5 shows graphs with obtained values of sidewall curvature R [mm] for a) tool with blank holder and b) tool with pressure pad. Higher values of curvature are geometrically closer to the straight sidewalls of U shaped part. Different values of blank holding pressure, pad pressure and friction coefficient were used for both steels DP600 and DC04. Graphs show that values of sidewall curvature R were in all cases higher for DC04 steel. Tool with pressure pad (tool b) shows higher values of sidewall curvature R than tool with blank holder (tool a). Higher coefficient of friction had positive effect on sidewall curvature R.

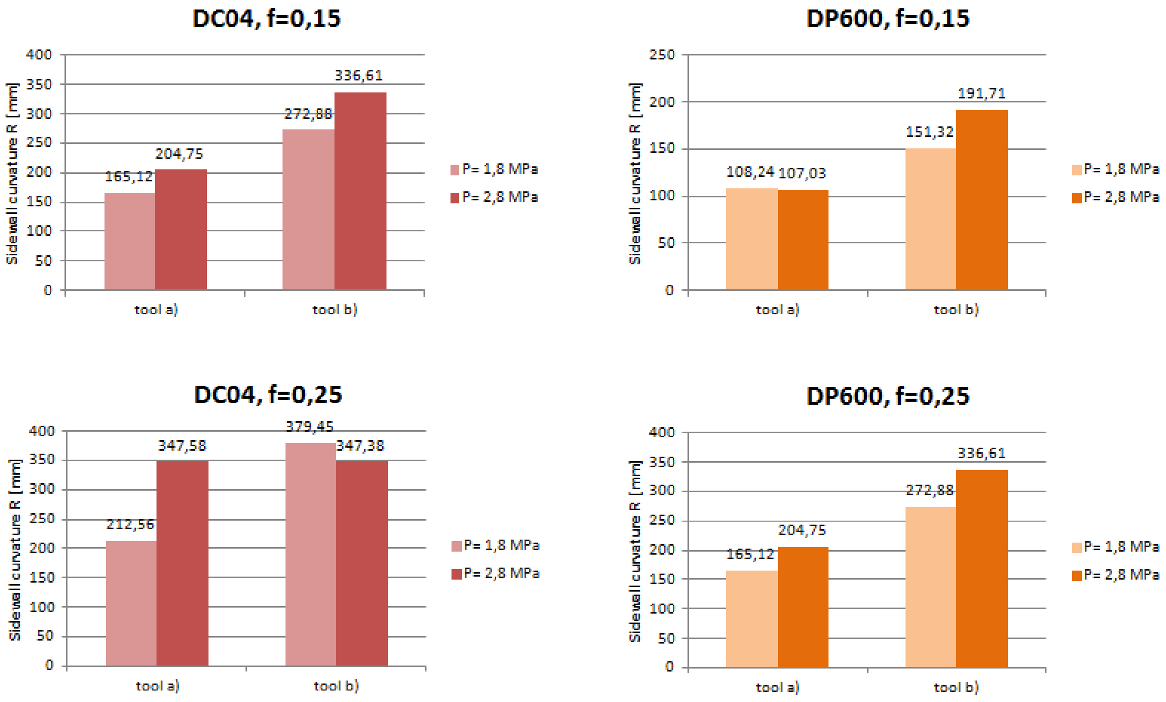


Fig. 5 Graphs showing sidewall curvature R for both steels with different values of pressure [MPa] and friction coefficient *f* [-]

IV. CONCLUSION

Springback of the U shaped part, made of DP600 steel was greater in comparison with low carbon steel DC04 (Fig. 6). The main reason for it may be the higher value of Yield stress in comparison with DC04 steel. Two values of blank holding pressure, pad pressure were tested – 1,8 MPa and 2,8 MPa in the forming simulation of the U - shaped part. Higher values of applied pressure by blank holder had positive effect on reducing springback, opening angle ß; it had also positive effect on sidewall curvature R. Higher pad pressure also had positive effect on reducing springback, but not in all cases.

Values of friction coefficient had significant effect on springback, opening angle ß and also on sidewall curvature R. Higher value of friction coefficient f= 0,25 showed less springback than value f= 0,15. It is probably because of higher strain applied during forming, which also means higher plastic deformation.

Tool with blank holder had in most cases lower values of opening angle ß than tool with pressure pad, there is difference about 30 % in opening angle between tools. But tool with pressure pad had better values of sidewall curvature R. So it is difficult to say which forming method, forming tool is better in reducing overall springback of the part.

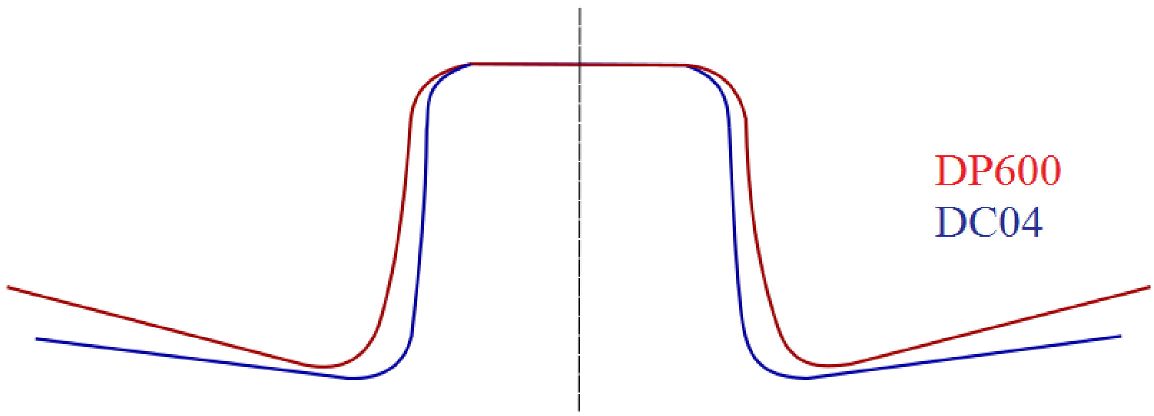


Fig. 6 Comparison of springback between DP 600 steel (red) and DC 04 steel (blue) for U – shaped part after springback calculation in tool with blank holder, value of the blank holder pressure was 1,8 MPa, value of coefficient of friction was 0,15

ACKNOWLEDGEMENTS

The authors are grateful to VEGA 1/0441/17.

REFERENCES

[1]. Jeswiet J, Geiger M, Engel U, Kleiner M, Schikorra M, Duflou J. , et al., Metal forming progress since 2000, *CIRP J Manuf Sci Technol* (2008), 2–17.
[2]. Banu M, Takamura M, Hama T, Naidim O, Teodosiu C, Makinouchi A. Simulation of springback and wrinkling in stamping of a dual phase steel rail-shaped part, *J Mater Process Technol* (2006), 173-178
[3]. B. Chongthairungruang, V. Uthaisangsuk, Springback prediction in sheet metal forming of high strength steels, *Materials and Design 50 (2013),* 253-266.
[4]. Larsson R, Bjoerklund O, Nilsson L, Simonsson K., A study of high strength steels undergoing non-linear strain paths – experiments and modelling. *Journal of Material and Process Technology 213* (2011), 122–132.
[5]. E. Spišák, J. Majerníková, Plastic deformation of tin coated steel sheet under different stress-strain states, *Progressive technologies and materials. 3- B: Materials,* 2009, 25-35.
[6]. Chongthairungruang, V. Uthaisangsuk, Experimental and numerical investigation of springback effect for advanced high strength dual phase steel, *Materials and Design 39 (2012),* 318-328.
[7]. J. Slota, E. Spišák, Determination of flow stress by the hydraulic bulge test, *Metalurgija, 47*(1), 2008, 13-17.
[8]. A. Sato, Journal of the Japan Society for Technology of Plasticity (JSTP). 46 (534), (2005), pp. 548-551
[9]. R. Wagoner, H. Lim, M.G. Lee, Advanced Issues in springback, *International Journal of Plasticity 45* (2013), 3–20
[10]. E. Spišák, J. Slota, J. Majerníková, The Analysis of Plastic Strain of Single and Double Reduced Tinplates, *Chemické listy, 105(*S), 2011, 485-487.
[11]. T. Yoshida, K. Sato, K. Hashimoto, Springback problems in forming of High-Strength steel sheets and countermeasures. Nippon steel technical report no. 103 may 2013
[12]. S. Toros, A. Polat, F. Ozturk, Formability and springback characterization of TRIP800 advanced high strength steel. *Materials and Design 41 (2012),* 298–305

Peter Mulidrán" Influence of forming method and process conditions on springback effect in the sheet metal forming simulation.” The International Journal of Engineering and Science (IJES), vol. 6, no. 12, 2017, pp. 62-67.