AN INVESTIGATION TO THE SPRINGBACK OF REVERSE CUP DRAWING

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STRACT: In this paper a FE simulation of springback in reverse cup drawing process, taken from MISHEET'99 benchmark is carried out, utilizing commercial code, ABAQUS. The forming process is ulated in ABAQUS/Explicit while the springback simulation is performed in ABAQUS/Standard. The zed method is probing a relationship between the springback and other important factors such as initial ık thickness die gap and type of material, i.e. Aluminum alloys and HSS. It will be shown that increasing initial blank thickness and decreasing the die gap leads to springback reduction in the cup. Considering required maximum punch load for different values of initial blank thickness and die gap reveals that e parameters should be controlled appropriately. Moreover, comparing the obtained results shows that sheets produced from HSS exhibit smaller amount of springback after unloading, however, they require :h larger punch load during the forming process.

YWORDS: Springback, reverse cup drawing, FE simulation

INTRODUCTION

ngback is generally defined as the additional ırmation of sheet metal parts when the loading :moved. Springback prediction has been under nsive research in the recent years due to the ınding use of aluminum and high strength ls in automotive stamping [1, 2]. Body panels ıped from these materials exhibit more ound springback characteristics than those e from mild steels. The deviation from a red shape due to springback introduces plexities and quality concerns during vehicle mbly stage. Therefore a thorough :rstanding of their springback behavior is cal to the design and manufacturing of the cle components.

:cent years, the rapid development of computer nology enables numerical simulation of sheet ıl forming operations by finite element analysis : to be used in an industrial environment. To in accurate numerical solutions, mechanical els implemented in FEA should use reliable riptions of materials' elastoplastic behavior, ely a description of anisotropy and work ening behaviors. Thus, more sophisticated stitutive models, which take into account non-ı: kinematic hardening and more complex nal state variables are expected to allow an improvement in the accuracy of the sheet metal forming simulation.

Oliveira et al. [3] evaluated several work hardening models in order to determine their influences on the numerical prediction of the springback phenomenon. They investigated the effect of different constitutive models on the numerical simulation of mild (DC06) and dual phase (DP600) steels submitted to several bending/unbending strain-path changes, during which a high level of equivalent plastic strain attained. Lee and Kim [4] focused on the evaluation of springback occurring in the sheet metal flange drawing by controlling some process factors like punch corner radius (PR), die corner radius (DR) and blank holding force. Esat et al. [5] carried out springback analysis of different aluminum sheets with different thicknesses and explored a relation between the amount of springback and total characteristic strain and also characteristic stress. They concluded that the material with higher yield strength and smaller characteristic strain has higher amount of springback than the material with lower yield strength and higher characteristic strain. Liu et al. [6] proposed a method to control the forming process of a U-shaped part by means of a reasonable blankholder force curve.

Springback is caused by the release of internal stress during the unloading phase in sheet metal forming, so the factors affecting the stress

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calculation accuracy will have an effect on the amount of springback. It may be indicated that the element size in FE analysis and the material's hardening model have greater effects on the stress calculation. The material's hardening model, viz the material's stress–strain relationship, expresses the basic properties of the material during plastic deformation. It is important to correctly select and reasonably pre-digest the stress–strain curve to enhance the accuracy of the springback simulation of bending with FE codes [7, 8].

In this paper the springback occurred in the reverse cup drawing process, taken from the NUMISHEET'99 benchmark, is numerically studied. Influence of initial sheet thickness, die gap and material type on springback is investigated by means of the FE software, ABAQUS.

2 FINITE ELEMENT MODELLING

Explicit models are nowadays widely utilized to analyze sheet metal forming processes since they allow fully 3-D geometry and complex contact conditions to be taken into account with relevant CPU savings with respect to the implicit algorithms (Li et al. [9], Li et al. [10], Onate et al. [11], Rebelo et al. [12]). At each time increment such models solve a set of independent dynamic equilibrium equations in order to upgrade the geometry of the meshed structure. No inversion of the stiffness matrix is needed, no numerical iterative procedure to get a satisfactory solution is required. In this way CPU time is saved and the incidence of plastic instabilities can be described well since the analysis continues even if diagonal terms of stiffness matrix approach to zero. However, as far as evaluation of the springback phenomenon is concerned, when the contact between the stamped part and the rigid dies is lost, the deformed sheet starts to oscillate around the new equilibrium position, until the accumulated kinetic energy is dissipated. As a consequence, the prediction of the elastic springback is a very time consuming step in explicit FEM analysis of sheet stamping processes. Actually a suitable amount of damping should be artificially introduced in order to accelerate the kinetic energy dissipation, but unfortunately, it is very difficult to evaluate the correct amount of damping to be applied. The commercial code ABAQUS used here provides such combined approach, incorporating a procedure by which the stress state at the end of the loading phase, obtained through a dynamic explicit FEM simulation carried out with ABAQUS/Explicit, is supplied to the implicit numerical code (ABAQUS/Standard) which performs a simple elastic step.

The reverse cup drawing problem in NUMISHEET'99 is the case studied here for three materials, i.e. Al6016-T4, Al6022-T4 and high strength steel (HSS). The geometry and the dimension of the tools are shown in Fig[illegible] quarter of the blank is modeled with a [illegible] *shell elements (S4R) with the symmetr*[illegible] conditions along the X and Y axis ([illegible] 2). Twenty five integration points thr[illegible] thickness are used in the modeling. Mass [illegible] used for dynamic explicit code are 2.[illegible] the aluminum alloys and 7.8 gr/cm^3 fo[illegible] strength steel. The major parameters ass[illegible] the process are:

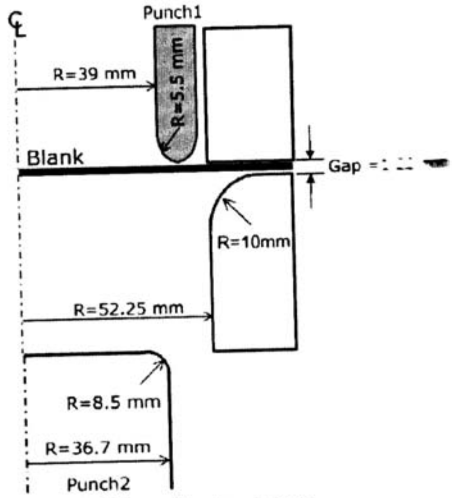


Figure 1: *Schematic view of tools*

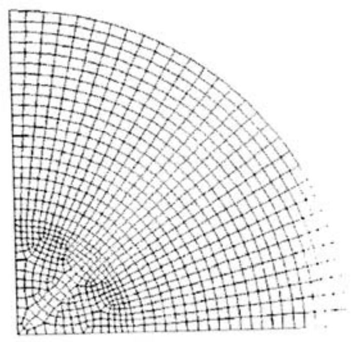


Figure 2: *One quarter of the blank used in simulations*

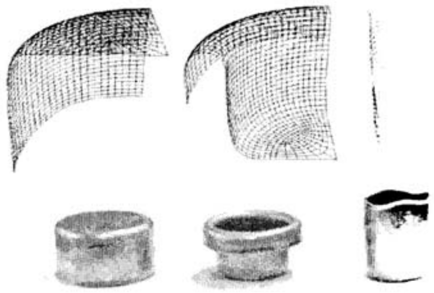


Figure 3: *Deformed shapes of the blank in thr[illegible] stages*

Blank diameter: 170mm
Coefficient of friction: 0.168

The reverse cup drawing process is composed of two stages; forward draw with total punch stroke of [illegible] (mm) and reverse draw with total punch stroke of [illegible]55 (mm). Figure 3 shows the complete deformed shape of the cup in three conditions for both numerical and experimental results [13]. When the anisotropy is considered, the earring predicted by the ABAQUS can be observed clearly in the experimental specimen. Instead of applying blank holder force in the model, fixed gap was considered between the blankholder and the die. In simulations, the punch velocity was increased to 15 [illegible] without mass scaling that resulted in very [illegible] oscillation in the kinetic energy which is [illegible]able for a quasi static process. In order to [illegible] the springback of the cup two parameters [illegible] considered, i.e. the mean edge radius and the [illegible] angel of the cup (theta), as shown in Figure [illegible]

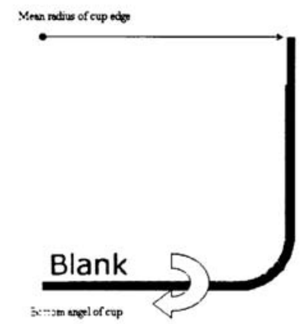


Figure 4: Springback definition for reverse cup [illegible] process

[illegible] EFFECT OF INITIAL THICKNESS

[illegible] thickness is one of the parameters that [illegible] affects on springback in sheet metal [illegible] which in fact may be utilized to control it. [illegible] other hand, increasing the initial sheet [illegible] causes increasing of required punch load [illegible] of the blank that are undesirable things [illegible] parameters. Therefore, finding the [illegible] value for initial sheet thickness is of vital [illegible] for the purpose of using suitable values [illegible] stage. In Figure 5, the relation [illegible] the value of initial blank thickness and the [illegible] of the cup is displayed. Three different [illegible] considered for this purpose, i.e. 1.05mm, [illegible] and 1.17mm. These values are chosen [illegible] that the two last ones are close to each [illegible] for better understanding of their [illegible] Simulations are performed for AL6016-T4 [illegible] assumed for the die gap. It is found [illegible] the initial value of the blank [illegible] apparently is a way of reducing [illegible] Paying more attention to the figure, displays that the springback amount for 1.15mm and 1.17mm initial thicknesses are considerably close. This fact demonstrates the sensitivity of springback to value of initial blank thickness in sheet metal forming. As mentioned earlier, the required maximum punch load is one of factors that may limit the value of the initial blank thickness. The results of required maximum punch load for the two stages are presented in Figure 6. The results verify clearly that using larger blank thickness in the process leads to requiring higher amount of maximum punch load. Investigating the results reveals that increasing the blank thickness of 1.05mm by 11% up to 1.17mm, causes 33% enlargement in the maximum punch load.

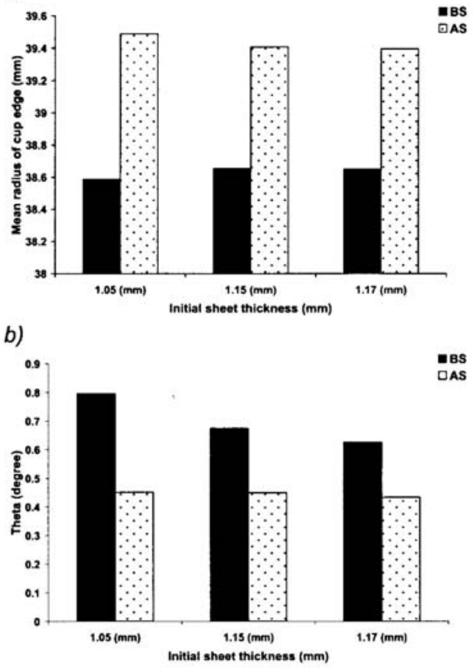


Figure 5: Influence of the initial sheet thickness on springback: a) mean radius of the cup edge, b) theta

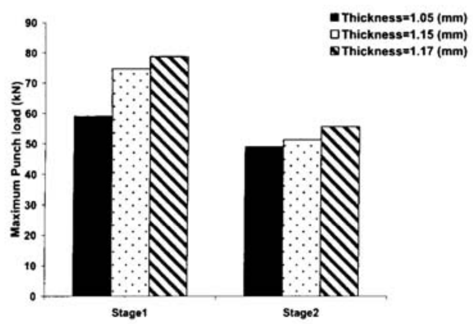


Figure 6: Required maximum punch load for different values of initial sheet thickness

2.2 EFFECT OF DIE GAP

Applying blankholder force in sheet metal forming processes is a way to control springback, because of affecting on the flow of the sheet into the die. But larger blankholder forces may cause the blank to tear or neck in side wall, therefore, the amount of blankholder force is limited. In the current study, a gap is considered between the die and the blankholder surfaces instead of applying force on blankholder. Different die gaps in the process lead to different amount of springback at the end. Three values are considered here in order to investigate the influence of die gap on springback for AL6016T4, i.e., NoGap, 1.22mm and 1.3mm, where the initial thickness is assumed to be 1.15mm for all cases. Figure 7 demonstrates the final amount of springback for the different values of the die gaps for the both springback parameters. It can be observed that the reduction of die gap causes decreasing of springback where it becomes a minimum for the NoGap condition. The maximum required punch loads for the two loading stages are compared to each other for different values of the die gaps. As it is expected, the NoGap condition requires the largest maximum punch load for the both stages, Figure 8. Thus, it may be taken into consideration that applying smaller value of die gap increases the maximum punch load.

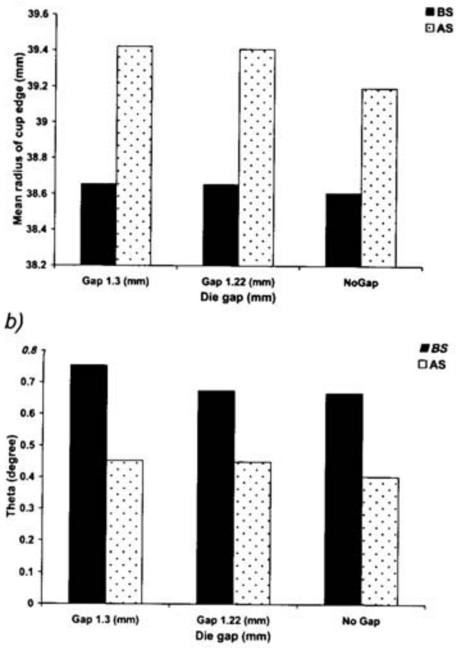


Figure 7: Influence of the die gap on springback: a) mean radius of the cup edge, b) theta

2.3 EFFECT OF MATERIAL

The relation between the springback and ... properties such as weight and strength ... material can affect on the materials' applic... industry. For instance, aluminum alloys ... strength steels have found expanding ... automotive industries. On the other han... panels stamped from these materials exhi... profound springback characteristics tha... made from mild steels. Therefore, a ... understanding of their springback beh... critical to the design and manufacturing ... vehicle components. The obtained res... springback for both mean radius of cup e... theta, and three different materials, i.e. Al... Al6022-T4 and high strength steel (HS... presented in the Figure 9. As it can be ob... the aluminum alloys exhibit more springb... the HSS. But, it should be noticed that th... thickness is considered the same for ... materials, therefore, HSS blank is tw... heavier than the aluminum blanks and it ... be an appropriate selection.

Figure 10 shows the maximum require... force for different materials. It is clear ... figure that the HSS needs a considerab... amount of maximum punch load in the ... process than the aluminum alloys. Hav... yield strength is one of the advanta... aluminum alloys which make their ... processes easier.

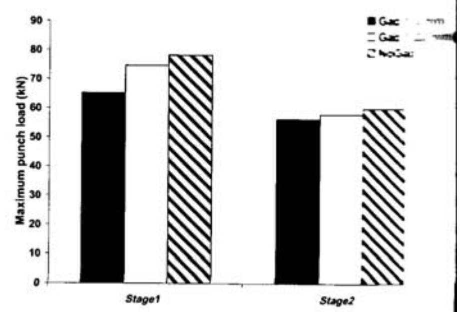
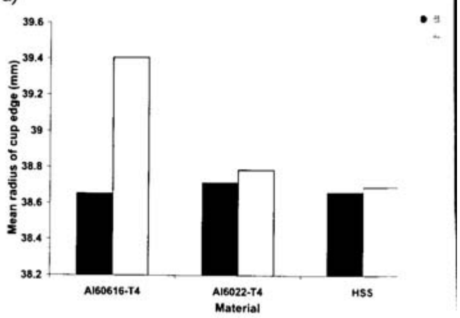
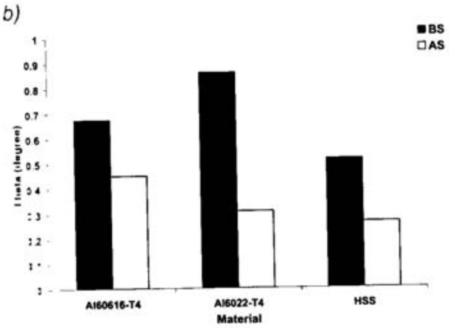


Figure 8: Required maximum punch ... different values of die gap

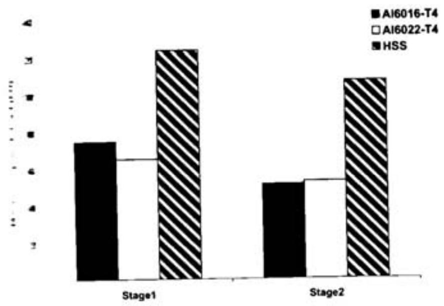
a)



b)



gure 9: Influence of the material on springback: ean radius of the cup edge, b) theta



gure 10: Maximum required punch load for materials

CONCLUSIONS

...ck of reverse cup drawing process, chosen ...MISHEET'99 benchmark, was studied ...y by means of the commercial FE ... ABAQUS. The influence of some ... factors such as initial blank thickness, ... and type of the material on the springback ... cup drawing was investigated. ... ned numerical results showed that ... the value of the initial thickness ... the springback of the deformed sheet, ... these cases more maximum required ... for both stages were needed. Hence, ... value of initial sheet thickness should ... The same discussion was valid for the ... decreasing of the die gap lead to ... reduction. Comparing different ... ealed that although HSS exhibited ... back than the aluminum alloys, but ... hand, HSS blank was heavier and it ... ost an appropriate feature in the ... cess.

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