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ACCURAY OF U BENT PARTS MADE ON ANISOTROPIC METAL SHEETS

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ABSTRACT

In this paper, the effect of different process parameters on the accuracy of U bent part made on anisotropic metal sheets is analyzed. The simulation of the U bending process is performed into ABAQUS software by using a 3D model. Hill's theory is adopted to describe the anisotropic material behaviour.

Keywords: U bent part, factors of influence, accuracy

1. INTRODUCTION

The capability of predicting the final geometry of parts made by metal sheets is an important feature in the sheet metal forming processes. In order to achieve specific product shapes without failures (such as springback, necking, wrinkling, fracture), finite element analysis (FEA) is nowadays largely used because it allows to check part and tools geometry at early design stage, as well as to optimize process parameters by minimizing the time and money consumption proper to the traditional trial-and-error approach.

In recent years considerable effort has been made in solving problems related to springback, (Samuel, 2000; Geng and Wagoner 2002; Viswanathan et al., 2003; Xu et al., 2004; Lee et al, 2005; Chung et al., 2005; Wagoner et al., 2006; Liu et al., 2007; Lee et al., 2008, Kim and Koc, 2008; Wei et al., 2008, Hama et al., 2008), because it causes deviations in the desired final shape and the part may not be within tolerance limits, stopping of being suitable for the application for which it was designed. By using finite element simulation, researchers and industrial practitioners can understand more about the springback behaviour and the effect of major factors such as tools geometry, material properties and process parameters on the springback amount.

Many commercial simulation codes, like LS-DYNA, PAM-STAMP, DYNAFORM, AUTOFORM, MARK, ABAQUS and so on, are used to study the sheet metal forming processes and their afferent phenomena. It is well known that, in general, an explicit solution scheme is suitable for the forming simulations to reduce computational cost and to relieve convergence problems. For the springback simulations, an implicit integration method is preferred for the accurate and efficient calculation of the unloading process. The optimal solution is then to have both implicit and explicit methods readily available in the same code and to be able to switch automatically from one to the other.

In this paper, an explicit dynamic procedure was used to perform a typical three-dimensional U bending process and its complementary implicit scheme was used to simulate the springback, by controlling two process parameters – the friction condition and the blankholder force, respectively.

Both, the loading and unloading processes were simulated by using the commercial available ABAQUS software: ABAQUS/Explicit for the loading process and ABAQUS/Standard for the unloading process).

2. FEA MODELING OF U BENDING PROCESS

Modelling of the U bending process requires the following inputs: geometric representation of tools (die, punch and blankholder), description of material behaviour (stress-strain relationship, anisotropy), and description of process parameters (blankholder force, friction condition, etc.).

Figure 1 shows the 3D finite element model used to simulate the U bending process. For simplicity, tooling elements were treated as rigid bodies and only the blank was considered deformable with a planar shell base (S4R element type). Five integration points was allocated along the thickness direction to take up the bending deformation. The diameter of the punch is 78mm and the punch radius is 10 mm. The outer diameter of the die is 180mm and inner diameter is 81mm with the entry radius of 5mm.

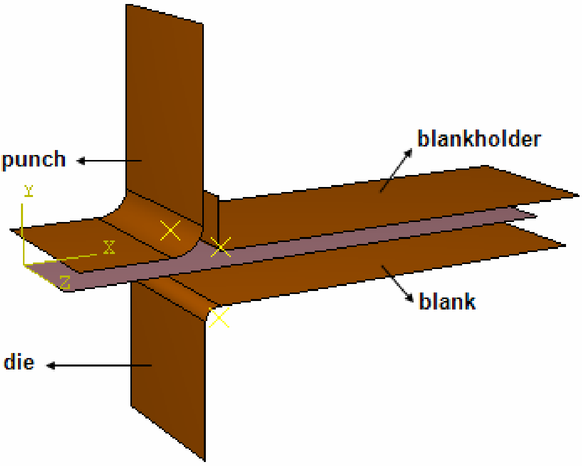


Figure 1. Model used in simulation

Penalty function-based contact interfaces was used to enforce contact and sliding boundary condition between the sheet metal and tooling elements. The penalty contact algorithm search the closest master segment/node for each slave node, computes orthogonal distance and if penetration exists, applies force proportional to penetration depth to master and slave nodes. When the master surface is formed by element faces, the master surface contact forces are distributed to the nodes of the master faces being penetrated. In the case of an analytical rigid master surface, the master surface forces are applied as forces and moments on the associated rigid body [13]. In the model taken for analysis, the deformable blank formed the slave side and the rigid tools formed the master side interface in the contact definitions.

The initial blank geometry was a rectangular shape, 350 mm×30 mm, and 0.8 mm in thickness. The material for the blank was FEPO 5MBH steel (table 1) and the anisotropic behaviour of this material was assumed (by using the Hill's potential function for planar deformation). The stress-strain curve of the material was implemented point by-point rather than using a curve fit equation.

The punch stroke was 50mm. Different blankholder force values (1.5, 2.5, 5, 10, 15 and 25 kN) were considered in simulation and two different coefficients of friction (0.1 and 0.075) were applied to the interface between the blank and tools surfaces, based on the Coulomb's low.

Table 1 Mechanical characteristics of the FEPO 5MBH steel

Orientation against rolling direction	**Young's modulus**	**Yield strength, [MPa]**	**Total elongation, [%]**	**Anisotropy coefficient, r**	**Hardening coefficient, n**
0^{o}	198000	306	34.7	0.82	0.234
45^{o}	200000	360	44.1	0.77	0.232
90^{o}	200000	375	26.1	0.81	0.233

3. SIMULATION RESULTS

The results of the forming process were imported into ABAQUS/Standard in order to simulate the unloading phase. The shape of parts was then obtained as a cloud of points, by post-processing the displacements resulted at the end of loading and unloading phases with the help of some macros and sheets of calculus.

The dimensional accuracy after springback was evaluated by three geometric quantities as illustrated in figure 2: the angle between the bottom and the wall (θ_1), the angle between the flange and the wall (θ_2), and the curvature (ρ) of the side wall. In the ideal cases of no springback, 90° angles of θ_1 and θ_2 and the flat side wall were expected.

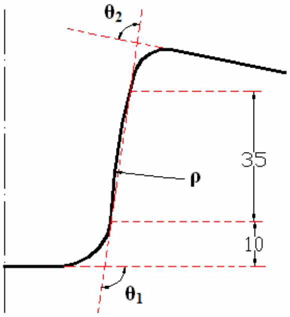
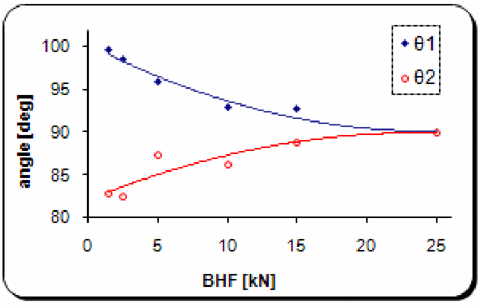


Figure 2. Parameters of springback

3.1. Case 1: springback parameters when different BHFs and μ = 0.1 were used

The variation of the three parameters that quantify the springback is presented in figure 3 and figure 4.



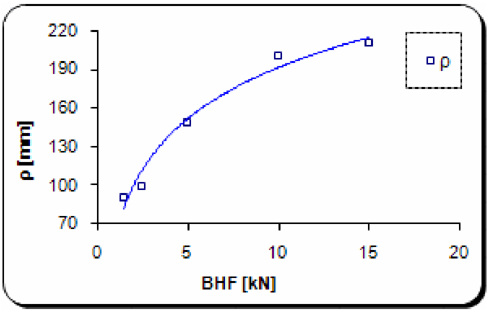
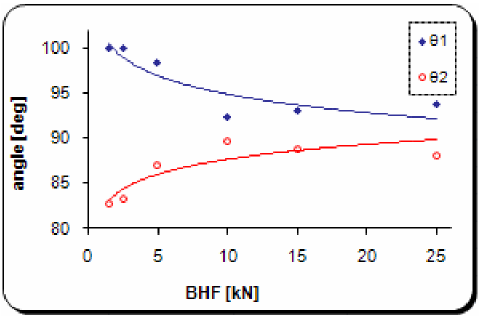


Figure 3. Variation of the springback angles *Figure 4. Variation of the side wall curvature*

3.2 Case 2: springback parameters when different BHFs and μ = 0.075 were used

The variation of the three parameters that quantify the springback is presented in figure 5 and figure 6.



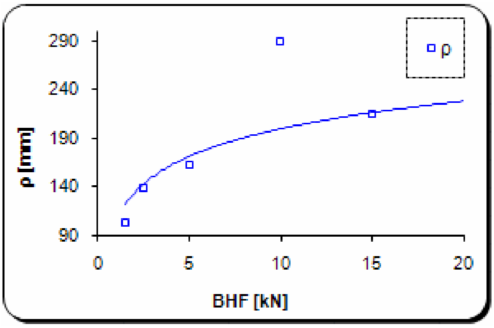


Figure 5 Variation of the springback angles *Figure 6 Variation of the side wall curvature*

4. CONCLUSIONS

As shown in figures 3 and 4, it was found that both, the angle between the bottom and the wall (θ_1) and the angle between the flange and the wall (θ_2), were significantly affected by the BHF: both of them tended to 90^o with BHF increasing. The side wall curvature (ρ) was getting bigger (it became flat for BHF = 25kN) as BHF increased. This trend of the three springback parameters could be explained by the fact that BHF increasing induces greater stresses inside the part and uniforms the stresses distribution through the sheet thickness (figure 7 and figure 8).

The same variation of the springback parameters was observed when a different coefficient of friction was used ($\mu = 0.075$). The angles θ_1 and θ_2 tended to 90^0 and the side wall curvature increased when higher BHFs were used. However, the values of these parameters were founded bigger than in the case when μ was 0.1. Thus, a higher friction coefficient between the blank and tools leads to some improvement of the part shape after unloading. The explanation could be considered from the same point of view with BHF since higher friction conditions increase the tension applied to the sheet and diminish the stress variation in the thickness direction.

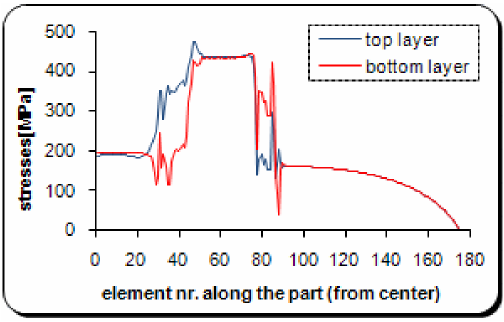


Figure 7. Stresses distribution, BHF=5kN, μ=0.1

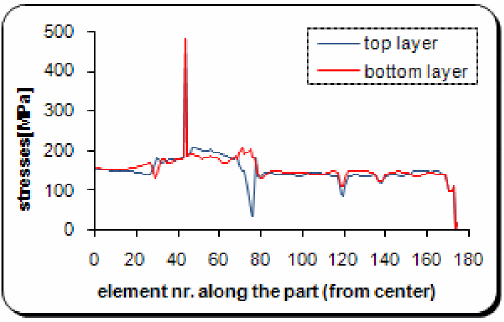


Figure 8. Stresses distribution, BHF=25kN, μ=0.1

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