The influence of the sheet thickness on springback effect in case of TWB’s forming

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Abstract—This paper presents the results obtained by numerical simulation regarding springback phenomenon of a part manufactured from tailor welded blanks. The final shape of the formed part is seriously affected by springback phenomenon. This paper work is trying to prove the important role the metal sheet thickness on the springback effect. The part has different springback values for each material from the welded assembly structure. The influence of the sheet thickness on the tailor welded stripes springback is examined by finite element method using Abaqus Standard for forming process and Abaqus Explicit for springback of the obtained part.

Keywords—tailor welded blanks, metal sheet thickness, springback.

I. INTRODUCTION

Recently, the automobile industries have been trying to develop various types of model and high-quality low-cost cars to meet the customer’s requirements and to find new ways of establishing this goal effectively. For the purpose of achieving the above presented objectives, different methods using various welding processes (such as laser-welding, mash seam-welding processes, etc.) were developed. A tailor welded blank consists of two or more sheets that have been welded together in a single plane prior to forming. The sheets can be identical, or can have different thickness, mechanical properties or surface coatings [1, 2, 3, 4]. Thickness of tailor welded sheets plays an important role in sheet metal forming since fracture, wrinkling and weak spots are strongly influenced by material behaviour.

The techniques of numerical analysis applicable for sheet metal forming have been considerably developed for the last several years. However, accurate prediction of the springback remains elusive [5, 6]. In finite element method (FEM) models of metal forming, the roughness has usually been assumed to be constant; even though it is commonly observed that sheet drawn under tension over a tool radius results in the surface becoming shiny, indicating a major change in surface morphology.

Many studies present a wide range of information about the formability and failure patterns of welded blanks [7]. A wide range of information about the formability and failure patterns of tailor-welded blanks and the springback of non-welded sheet metal parts has been presented. However, the springback characteristics of tailor-welded blanks have hardly been found [8, 9]. Published results on springback prediction of tailor welded blanks are minimal [11].

Since the springback is also affected by the material properties, such as Young’s modulus and initial yield stress, the process design for tailor-welded blanks is more complicated than for a homogenous metal sheet. Though novel approaches relating to the formality of tailor-welded blanks are available, the change of springback due to the characteristic of each process should be verified by finite element method [11].

In this study, the tailor welded blanks with two types of material having the same thickness, are used to investigate springback characteristics in U-shape forming.

Springback (Fig. 1) is mainly influenced by the sheet thickness, the punch and die profile radii, initial clearance between punch and die, friction conditions, rolling direction of the materials, blankholder force, material properties (elastic modulus, Poisson’s coefficient, constitutive behaviour in plastic field) etc. The purpose of this study was to investigate the sheet thickness influence on the springback effect of the tailor-welded stripes. To achieve this goal, simulation tests were carried with different sheet thickness of the laser welded assembly.

II. MECHANICAL PROPERTIES OF MATERIALS

To obtain the mechanical properties of the base materials and of the welding line, tensile tests were performed on a universal mechanical testing machine, equipped with Hottinger force cells of 5 t and a Hottinger – Baldwin electronic measurement system for PCs – type Spider 8. The data acquisition, processing and visualisation were performed using Catman Express software. The measurement of specific strains for determination of stress - strain curves was performed using an Epsilon extensometer for a strain rate of 0.1 s⁻¹.
To determine the mechanical properties of the welding line, from the original TWB, a 4 mm wide stripe which includes the welding line, has been removed using EDM wire cutting (Fig. 2).

![Fig. 2 sample used to determine the mechanical properties of the welding line](image)

The flow stress and true total strain were calculated for each recorded couple of the force and displacement. The total strain was decomposed on elastic strain and plastic strain using determined Young module. To obtain a better accuracy of FEM modeling, especially in the range of small deformation, there was resigned the functional stress – strain curves in favor of the stress – strain curves in the numerical form.

The mechanical properties of FEPO steel and E220 steel determined for 0° and 90° are presented in table no 1. In the table below are presented also, the mechanical properties of the welding line.

### TABLE 1

**MECHANICAL PROPERTIES**

<table>
<thead>
<tr>
<th>Property</th>
<th>FeP0</th>
<th>E220</th>
<th>weld</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength R_p0,2 [MPa]</td>
<td>203</td>
<td>268</td>
<td>252</td>
</tr>
<tr>
<td>Tensile strength R_m [MPa]</td>
<td>381</td>
<td>458</td>
<td>417</td>
</tr>
<tr>
<td>Percentage elongation after fracture A_u [%]</td>
<td>31,8</td>
<td>19,8</td>
<td>17,3</td>
</tr>
<tr>
<td>Elongation for max. Load A_p [%]</td>
<td>0,222</td>
<td>0,190</td>
<td>0,180</td>
</tr>
<tr>
<td>Strain-hardening coefficient n</td>
<td>1,860</td>
<td>1,420</td>
<td>1,29</td>
</tr>
<tr>
<td>Plastic strain ratio r</td>
<td>2,430</td>
<td>1,650</td>
<td>0,286</td>
</tr>
<tr>
<td>Poisson's ratio v</td>
<td>0,294</td>
<td>0,232</td>
<td>0,278</td>
</tr>
<tr>
<td>Young modulus E [MPa]</td>
<td>200825</td>
<td>204271</td>
<td>203253</td>
</tr>
</tbody>
</table>

The materials microstructure has been analysed using a metallographic microscope with a magnification of 100X for base materials and 500X for welding line. The materials have uniform, typical microstructure with fine grain. The microstructure is shown in Fig. 4.

![Fig. 4 the material microstructure](image)

### III. ANALYSIS BY SIMULATION

#### A. Simulation methodology

The simulation of the U - shape part draw bending was made by using the ABAQUS software. The analyzed geometrical parameters are sidewall radius ρ and springback angles θ₁ and θ₂ (Fig. 5). The simulations considered a plane strain state. The material was modelled as elastic-plastic, the plastic behaviour being modelled as anisotropic using the Hill’s quadratic anisotropic yield criterion.

![Fig. 5 springback parameters](image)

The initial dimensions of the sheet were 350 mm length and 30 mm width, with thickness variation from 0,8 till 1,3 mm. For determination of the sheet thickness influence on springback phenomenon, the simulations have been done under the following conditions: the sample model is loaded with the material characteristics corresponding to 0° rolling direction; blank holder force F = 15 kN; the friction coefficient between the specimen and tools surfaces is 0,1, the thickness of the sample model are 0,8, 0,9, 1,0, 1,1, 1,2 and 1,3 mm. Figure 6 presents the initial and the final state of the forming process in case of the U shaped part made from TWB’s.

![Fig. 6 geometrical model](image)
The sheet was modelled as deformable body with 400 shell elements (S4R) on one row with 5 integration points through the thickness. The tools (punch, die and blankholder) were modelled as analytical rigid body. This modelling will lead to a reduced calculus efforts and a better contact behaviour. The rigid body movements were controlled by the reference points.

The boundary conditions imposed to the tools were intended to describe as accurate as possible the experimental conditions. A modified Coulomb friction law combined with penalty method was used to describe the contact condition.

B. Simulation results

The values of springback parameters resulted from the simulation tests are graphical represented in figures 7, 8 and 9.

![Fig. 7 variation of θ₁ angle](image1)

![Fig. 8 variation of θ₂ angle](image2)

![Fig. 9 variation of sidewall curvature radius ρ](image3)

Parts having different thickness are affected in a dissimilar mode by the springback phenomena. The values of springback parameters are recorded in table 2.

<table>
<thead>
<tr>
<th>Metal sheet thickness [mm]</th>
<th>Angle θ₁ [ grd]</th>
<th>Angle θ₂ [ grd]</th>
<th>Sidewall radius [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theoretic value</td>
<td>Measured value</td>
<td>Theoretic value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8</td>
<td>100.6</td>
<td>14.9</td>
<td>205.0</td>
</tr>
<tr>
<td>0.9</td>
<td>99.7</td>
<td>14.1</td>
<td>307.6</td>
</tr>
<tr>
<td>1.0</td>
<td>99.0</td>
<td>13.4</td>
<td>385.8</td>
</tr>
<tr>
<td>1.1</td>
<td>96.8</td>
<td>10.3</td>
<td>1524.0</td>
</tr>
<tr>
<td>1.2</td>
<td>95.1</td>
<td>7.6</td>
<td>2875.5</td>
</tr>
<tr>
<td>1.3</td>
<td>93.6</td>
<td>5.5</td>
<td>3347.3</td>
</tr>
</tbody>
</table>

IV. Conclusion

From the analysis of figure 10 and table 2, the following observations can be presented concerning the influence of the sheet thickness on springback parameters:

- the modification of sheet thickness leads to important variations of springback parameters;
- increasing of the sheet thickness results in reduction of the springback effect, the final geometry of the formed part is closer to the ideal part shape;
- variation of the springback phenomenon proportional with sheet thickness is observed for both areas of the part;
- for sheet thickness over 1.0 mm the sidewall radius increases so much, that it can be considered a straight line;
- the springback parameters from the part zone made from FEPO steel record smaller values for both angles θ₁ and θ₂ with respect to the E220 part area;
- the part area made by E220 present a springback intensity higher that the part area made from FEPO steel.

REFERENCES

Fig. 10 final shape of the TWB’s affected by springback phenomenon


