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THE SHEET THICKNESS EFFECT ON SPRINGBACK AMPLITUDE OF A U-SHAPED PART MADE FROM TAILOR WELDED STRIPES

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ABSTRACT

This paper presents the results obtained by numerical simulation regarding springback phenomenon of a part manufactured from tailor welded stripes. 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: forming, springback, tailor welded stripes.

1. 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]. 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 [2]. 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 presents a wide range of information about the formability and failure patterns of welded stripes. A wide range of information about the formability and failure patterns of tailor-welded stripes and the springback of non-welded sheet metal parts has been presented. However, the springback characteristics of tailor-welded stripes have hardly been found [3]. Published results on springback prediction of tailor welded stripes are minimal. The welding line was insignificant influence when is placed perpendicular to the direction of the deformation force [4].

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 stripes is more complicated than a homogenous stripe. Though novel approaches relating to the formality of tailor-welded stripes are available, the change of springback due to the characteristic of each process should be verified by finite element method.

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

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.

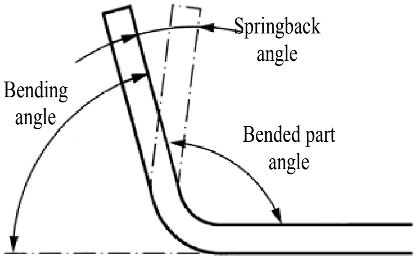


Fig. 1. Scheme of the bending process and springback

2. MATERIAL PROPERTIES

Simulation of the forming processes based on finite element method using ABAQUS software requires as input data the mechanical properties of the used materials. Determination accuracy of the mechanical properties has an important influence on simulation results.

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 tf 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}.

The specimens were cut as a function of the rolling direction being achieved sets of specimens corresponding to the direction of 0º and were worked by milling and grinding in order to obtain the prescribed dimensions. The reference length of the specimen was equal to 50 mm. To obtain a good accuracy of the results, 3 specimens were tested for each determination.

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

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 modelling, especially in the range of small deformation, there was resigned the functional stress – strain curves in favour of the stress – strain curves in the numerical form.

The mechanical properties of FEPO steel and E220 steel determined for 0º material rolling direction are presented in Table 1. In the table below are presented also, the mechanical properties of the welding line. In Figure 3 are presented the stress – strain curves for FEPO ans E220 steels and for the welding line material.

Table 1. Mechanical properties

Property	FEPO	E220	weld
Yield strength $\mathbf{R_{p0,2}}$ [MPa]	203	268	252
Tensile strength **Rm** [MPa]	381	458	417
Percentage elongation after fracture $\mathbf{A_{80}}$ [%]	–	35,3	–
Elongation for max. load $\mathbf{A_{gt}}$ [%]	31,8	20,4	17,3
Strain-hardening coefficient **n**	0,222	0,190	-
Plastic strain ratio **r**	1,860	1,420	1,29
Poisson's ratio **ν**	0,286	0,297	0,278
Young modulus **E** [MPa]	200825	204271	203253

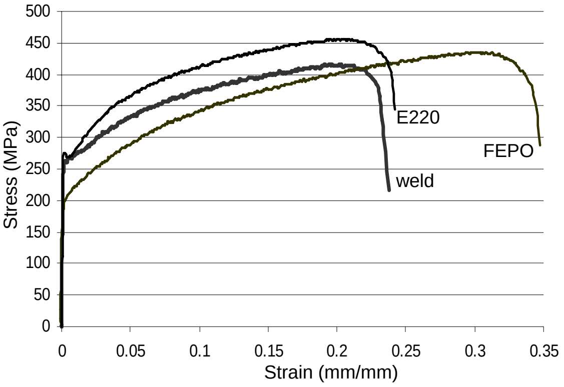
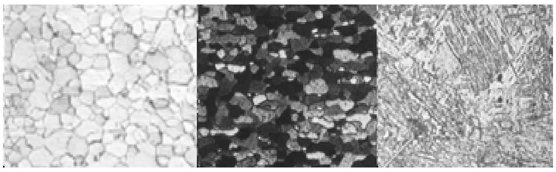


Fig. 3. Stress – strain curves for 0º

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 Figure 4.



E220 FEPO weld

Fig. 4. The material microstructure

3. SIMULATION OF THE FORMING PROCESS

The simulation of U-shape part forming was made using finite element method. The objective is to create a model that allows an accurate prediction of springback intensity, stress and strain state at the end of the forming process. The analyzed geometrical parameters are sidewall radius ρ and springback angles θ_1 and θ_2.

The tailor welded stripes used in the simulation tests were made from FEPO and E220 steel. Stripes of 350 mm length and 30 mm wide, with thickness variation from 0,8 till 1,3 mm (Fig. 5).

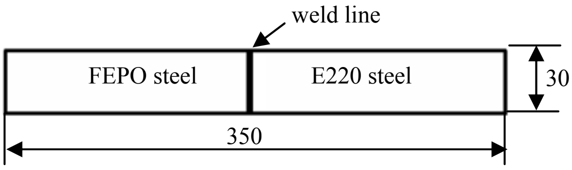


Fig. 5. Tailor welded strips with transversal weld line

The material was modelled as elastic-plastic, where elasticity is considered isotropic and plasticity is modelled as anisotropic using Hill quadratic anisotropic yield criterion.

In this simulation, fine mesh technology was applied to interested regions such as the punch profile radius and the tailor-welded strip model to improve the accuracy of the analysis for the springback.

The geometrical model is presented in Figure 6. 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 because they have the advantage of reduced calculus efforts and a good contact behaviour. Rigid body movements are controlled by reference points.

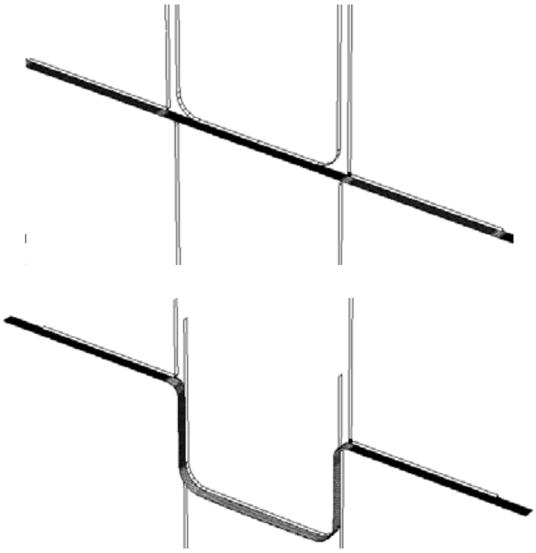


Fig. 6. Geometrical model

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

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.

Springback parameters that were observed during the simulation tests are presented in Figure 7:

- θ_1 – sidewall angle between real profile and theoretical profile;
- θ_2 – flange angle between real profile and theoretical profile;
- ρ – curvature radius of the sidewall.

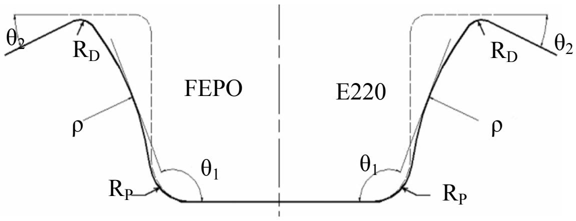


Fig. 7. Springback parameters

4. SIMULATION RESULTS

In Figure 8 are presented the tailor weld stripes with different thickness, after the forming tools have been removed. Parts having different thickness are affected in a dissimilar mode by the springback effect.

The values of springback parameters are recorded in Table 2.

5. CONCLUSION

From the analysis of Figure 8 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 θ_1 and θ_2 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.

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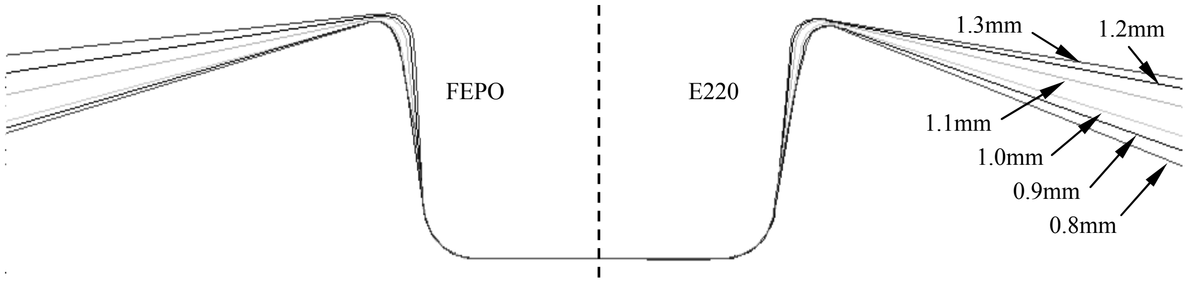

Fig. 8. Shape of the TWB deformed by springback phenomenon

Table 2. Springback parameters

	FEPO steel						E220 steel					
TWB thickness [mm]	Angle θ_1 [degrees]		Angle θ_2 [degrees]		Sidewall radius [mm]		Angle θ_1 [degrees]		Angle θ_2 [degrees]		Sidewall radius [mm]	
	Nominal value	Obtained value	Nominal value	Obtained value	Nominal value	Obtained value	Nominal value	Obtained value	Nominal value	Obtained value	Nominal value	Obtained value
0.8	90	100.6	0	14.9	∞	205.0	90	102.8	0	19.3	∞	188.4
0.9		99.7		14.1		307.6		101.0		17.5		265.7
1.0		99.0		13.4		385.8		100.1		15.6		322.9
1.1		96.8		10.3		1524.0		98.2		11.8		818.5
1.2		95.1		7.6		2875.5		96.7		9.5		2106.6
1.3		93.6		5.5		3347.3		95.6		8.3		3071.5