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ROLLING DIRECTION INFLUENCE ON THE SPRINGBACK EFFECT OF AN U-SHAPEED PART MADE FROM TAILOR WELDED BLANKS

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Abstract: *This paper deals with numerical simulation and experimental tests related to forming and springback of a U-shape part manufactured from tailor welded stripes. Final shape of the parts manufactured by tailor welded stripes is seriously affected by springback effect. This paper work is trying to prove out the important role that the rolling direction has on the springback reduction. The influence of the rolling direction on the tailor welded stripes springback is examined using the simulation by finite element method (ABAQUS). Experimental tests have been carried out using two different rolling directions and maintaining constant all other parameters.*

Key words: *tailor welded stripes, springback, rolling direction, finite element method.*

1. INTRODUCTION

A tailor welded stripe consists of two sheets that have been welded together in a single plane prior to forming. The sheets joined by welding can be identical, or they can have different thickness, mechanical properties or surface coatings. Various welding processes, *i.e.* laser welding, mash welding, electron-beam welding or induction welding, can join them [1]. And, 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]. Many studies present 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 [3–5]. 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 [6].

The rolling direction of the materials with respect to the deformation direction can greatly influence on springback as well as formability. 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 [7].

In this study, the tailor welded stripes (joined together without taking in consideration the welding line) with two types of material having the same thickness, are used to investigate springback characteristics in U-shape bending.

The welding line can be oriented in three different ways with respect to the materials rolling direction (Fig. 1), as follows: parallel, inclined, and perpendicular to the rolling direction. This study will investigate only the parallel and perpendicular position.

Springback (Fig. 2) is mainly influenced by 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. [8–11]. The purpose of this study was to investigate the material rolling direction influence for minimizing the springback effect of the tailor-welded stripes. To achieve this goal, simulation and experimental test were carried with different material rolling direction.

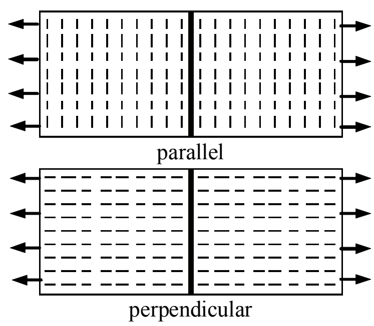

Fig. 1. Different orientation of the welding line with respect to the rolling direction.

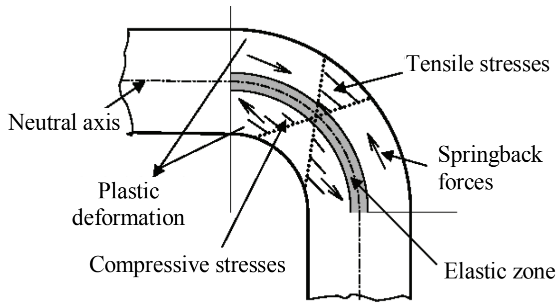

Fig. 2. Bending of sheet metal.

2. EXPERIMENTAL TESTS CONCERNING THE INFLUENCE OF MATERIAL ROLLING DIRECTION

2.1. Experimental layout

The tailor welded stripes used in the experiments were made from FEPO and E220 steel. Strips of 350 × 30 mm

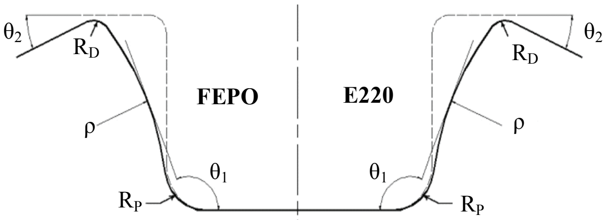

Fig. 3. Springback parameters.

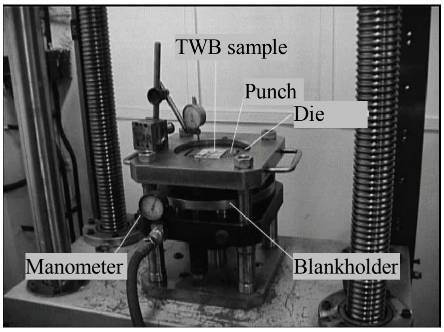

Fig. 4. Experimental device.

dimensions and 0.7 mm thickness were cut from the metal sheet along and perpendicular to the rolling direction. The samples were cut at 0° and 90° to rolling direction. Springback parameters that were observed during the tests are presented in Fig. 3:

- 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.

The experimental researches were realized using a die for rectangular parts and a 10 kN blank holder force. The device is presented in Fig. 4. Tool geometry is presented in Table 1. The forming force was generated using a mechanical tensile test machine. The profile of the obtained part and the parameters of springback were measured with a numerical controlled scanning machine Roland Model MDX-15, and the obtained data were processed with CAD software.

2.2. Experimental results concerning the influence of rolling direction

In order to experimentally determine the influence of rolling direction on springback parameters, the results for specimens cut out at angles 0° (*RD* is perpendicular in the weld line) and 90° (*RD* is parallel with the weld line) to rolling direction were compared. To minimize the influence of the blank holder force, its value was constant at 10 kN.

The forming tests have been done with lubrication of the tools and of the TWB sample.

The values of springback parameters are recorded in Table 2.

From the above presented data and from the charts presented bellow the following observation can be presented:

- modification of the rolling direction determine small variation of springback parameters;
- angle values of θ_1 (Fig. 5) and θ_2 (Fig. 6) are bigger when rolling direction of the TWB sample is along with deformation direction;
- sidewall radius ρ are smaller when the TWB sample has the rolling direction parallel with deformation direction (Fig. 7);
- springback intensity is smaller in part area made from FEPO in comparison with E220 steel area.

Table 1

Die geometric parameters

Punch geometry [mm]	78 × 120
Punch profile radius [mm]	10
Die opening [mm]	80
Die profile radius [mm]	5
Punch stroke [mm]	50

Table 2

Springback parameters

Rolling direction [grd]	FEPO					
	Angle θ_1 [grd]		Angle θ_2 [grd]		Sidewall radius [mm]	
	Theoretic value	Measured value	Theoretic value	Measured value	Theoretic value	Measured value
0°	90	97.8	0	11.5	∞:	262.84
90°	90	95.9	0	10.6	∞	371.16
	E220					
Rolling direction [grd]	Angle θ_1 [grd]		Angle θ_2 [grd]		Sidewall radius [mm]	
	Theoretic value	Measured value	Theoretic value	Measured value	Theoretic value	Measured value
0°	90	100.3	0	17.1	∞	214.82
90°	90	97.8	0	15.4	∞	289.12

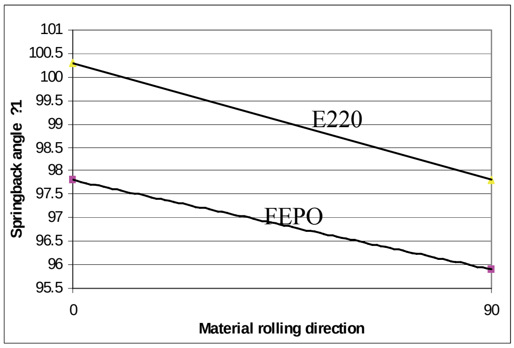

Fig. 5. Variation of angle θ_1.

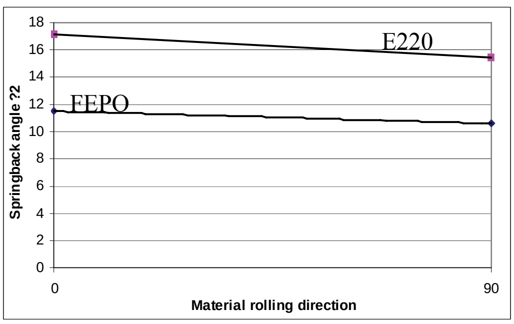

Fig. 6. Variation of angle θ_2.

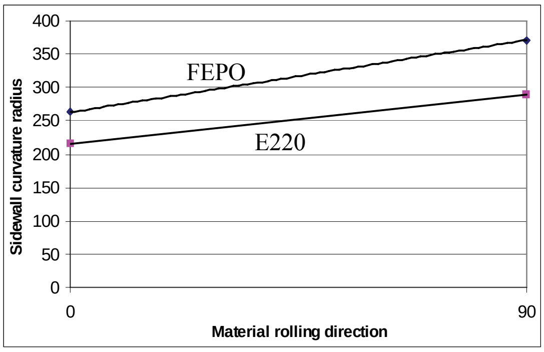

Fig. 7. Variation of sidewall curvature radius ρ.

3. ANALYSIS BY FINITE ELEMENT METHOD OF THE INFLUENCE OF MATERIAL ROLLING DIRECTION ON SPRINGBACK PHENOMENON

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. In order to validate the model, the results of the FE analysis were compared with the experimental results.

3.1. Simulation methodology

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

In order to validate the model, the results of the FEM analysis were compared with the experimental results.

The geometrical model is presented in Fig. 8. The initial dimensions of the sheet were 350 mm length, 30 mm width and 0.7 mm thick. 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.

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.

3.2. Simulation results concerning the influence of rolling direction

The distribution of the stresses on the two faces of the part before and after springback is illustrated in Fig. 9.

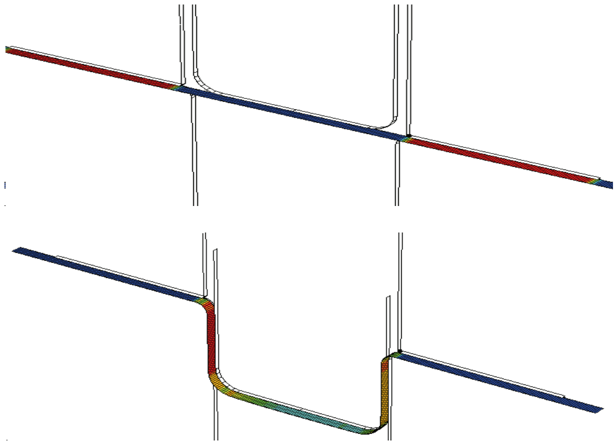

Fig. 8. Geometrical model.

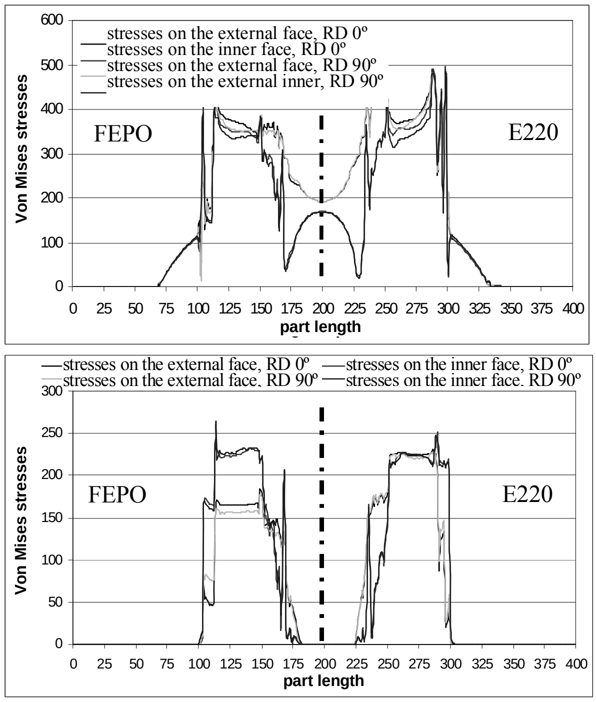

Fig. 9. Equivalent stress distribution along the faces of the part before and after springback.

The variations of springback parameters (θ_1, θ_2, ρ) as function of material rolling direction are presented graphically in Table 3.

Table 3

Springback parameters

Rolling direction [grd]	Angle θ_1 [grd]		Angle θ_2 [grd]		Sidewall radius [mm]	
	FEPO					
	Theoretic value	Measured value	Theoretic value	Measured value	Theoretic value	Measured value
0°	90	99.2	0	13.8	∞:	203.93
90°	90	97.1	0	11.7	∞	318.72
	E220					
	Theoretic value	Measured value	Theoretic value	Measured value	Theoretic value	Measured value
0°	90	101.4	0	18.4	∞	103.34
90°	90	99.3	0	16.3	∞	154.49

Table 4

Springback parameters

Rolling direction [grd]	Angle θ_1 [grd]		Angle θ_2 [grd]		Sidewall radius [mm]	
FEPO						
	Exp. test	Sim. test	Exp. test	Sim. test	Exp. test	Sim. test
0°	97.8	99.2	11.5	13.8	262.84	203.93
90°	95.9	97.1	10.6	11.7	371.16	318.72
E220						
Rolling direction [grd]	Angle θ_1 [grd]		Angle θ_2 [grd]		Sidewall radius [mm]	
	Exp. test	Sim. test	Exp. test	Sim. test	Exp. test	Sim. test
0°	100.3	101.4	17.1	18.4	214.82	103.34
90°	97.8	99.3	15.4	16.3	289.12	154.49

From the above presented results the following aspects can be remarked: the modification of the rolling direction affects the springback parameters of the U-shaped part; the values of θ_1 and θ_2 angles attains higher values when the part is made from TWB having the rolling direction parallel to the deformation direction; the sidewall radii ρ are smaller when the TWB sample has the rolling direction parallel to the deformation direction; the part area made from FEPO is not so much affected by the springback phenomenon in comparison with E220 steel area for both rolling directions.

3.3. Comparison of the results obtained experimentally and by simulation

In order to validate the results obtained by finite element analysis it is necessary to compare these results with the ones generated by experimental analysis.

Analyzing the springback parameters variation charts obtained experimentally and by simulation, the results leads to the following conclusions:

- the tendencies are the same for both experimental or simulation results for every factor;
- the results of finite element analysis have a small tendency to overestimate the intensity of springback compared to experimental results (Table 4);
- the difference between the experimental and simulation test are caused by the assumed uniform blank-holder pressure, which is not uniform in reality;
- it can be considered that the results generated by the analysis of springback phenomenon using finite element method are sufficiently accurate and can be considered valid.

4. CONCLUSIONS

The following aspects stand out from the experimental researches of the influence of the rolling direction on springback parameters:

- forming against the rolling direction (90º) leads to reduction of springback intensity. Bending with the grain (0º) may result in cracking or even breaking in the deformation area;
- the grain placed on the part bottom and flange suffer only tensile stresses and no springback effect appear on those areas. The sidewall curvature appears because the grains placed on the both sides of the neutral axis are bended with different values during the forming process and the stress difference between them determines material deformation after the part is released.
- because during the forming process the material placed closed to the neutral axis suffer only elastic deformation at the punch and die profile radius the springback phenomenon is more evident;
- the springback of FEPO material is smaller comparing with E220 material, because the strength of the E220 steel is higher that the strength of FEPO steel.

The results of finite element analysis have a small tendency to overestimate the intensity of springback compared to experimental results. It can be considered that the results generated by the analysis of springback phenomenon using finite element method are sufficiently accurate and can be considered valid. When properly used, simulation by finite element method can be considered a valuable tool in the study of the influencing factors of the springback phenomenon able to offer accurate data even from the design stage.

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