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SPRINGBACK BEHAVIOUR OF A PART MADE FROM TAILOR WELDED BLANKS FOR DIFFERENT WELDING LINE PLACEMENT

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ABSTRACT
This paper refers to some numerical simulation and experimental tests related to forming and springback of a part manufactured from tailor welded blanks. Final shape of the formed part is seriously affected by springback effect. This paper work is trying to prove out the important role of welding line placement has on the springback phenomenon. The influence of the welding line placement on the tailor welded blanks springback is examined using the simulation by finite element method (ABAQUS). Also, experimental tests have been carried out using different placements of the welding line and maintaining constant all other parameters. A comparison between simulation and experiment results is presented in the final section of this paper.
Keywords: tailor welded blanks, welding line placement, springback.

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 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 [3–5]. Published results on springback prediction of tailor welded stripes are minimal.
In case of U-shape forming of tailor welded stripes, the welding line placement has great influence on springback phenomenon, even the welding line is placed perpendicular to the direction of the deformation force [6, 7].
In this study, the tailor welded stripes with two types of material having the same thickness bud different mechanical properties, are used to investigate springback characteristics in U-shape forming.

2. EXPERIMENTAL RESEARCHES REGARDING THE WELDING LINE INFLUENCE
The tailor welded stripes used in the experiments were made from FEPO and E220 steel. Strips of 350×30 mm dimensions and 0.7 mm thickness were cut from the metal sheet along to the material rolling direction. The experimental tests were realized using a die for rectangular parts that allowed utilization of different blank holder forces. The experimental tests have been done with varied welding line placement with respect to the part axis. The blankholder force was maintained constant to 10 kN. 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 was processed in CAD software.
Springback parameters that were observed during the tests are presented in figure 1:

- 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.

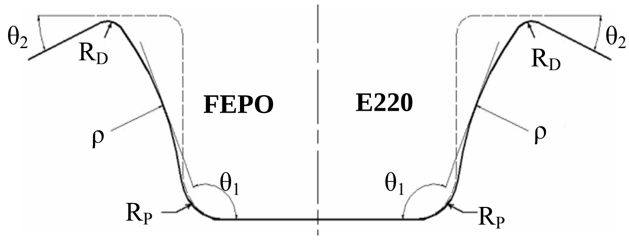

Figure 1. Geometrical springback parameters

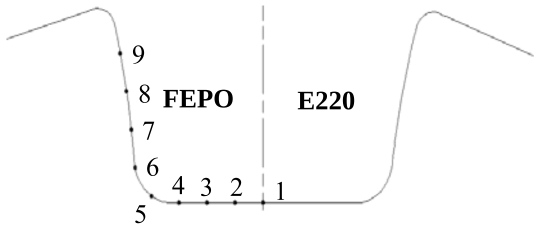

Figure2. Welding line position after forming

In order to experimentally determine the influence of the welding line placement on springback parameters, the samples have been cut along to the material rolling direction (RD is perpendicular to the weld line). Initially the welding line was placed on the central axis of the part, on the following tests the welding line was moved each time toward to the FEPO steel with 8.7 mm. To minimize the influence of the blank holder force, its value was constant at 10kN. The forming tests have been done with lubrication of the tools and of the tailor welded stripes sample. The values of springback parameters are recorded in table 1.

Table 1. Springback parameters

Welding line displacement [mm]	Zone of the part made from FEPO steel						Zone of the part made from E220 steel					
	Angle θ_1 [grd]		Angle θ_2 [grd]		Sidewall Radius [mm]		Angle θ_1 [grd]		Angle θ_2 [grd]		Sidewall Radius [mm]	
	Ideal	Measured	Ideal	Measured	Ideal	Measured	Ideal	Measured	Ideal	Measured	Ideal	Measured
0.00		99.14		13.64		203.72		101.31		18.43		103.31
8.75		99.31		13.67		203.96		101.29		18.41		103.37
16.5		99.23		13.79		203.86		101.42		18.45		103.39
26.25		99.25		13.84		203.84		101.45		18.43		103.34
35.00	90	100.75	0	14.31	∞	191.59	90	101.35	0	18.42	∞	103.32
43.75		101.45		16.21		182.08		101.37		18.44		103.33
52.50		102.53		17.62		170.21		101.41		18.41		103.34
61.25		102.81		18.37		160.79		101.39		18.39		103.36
70.00		103.12		19.12		151.00		101.42		18.38		103.38

3. SIMULATION RESEARCHES REGARDING THE WELDING LINE INFLUENCE

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

The geometrical model is presented in figure 3. 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.

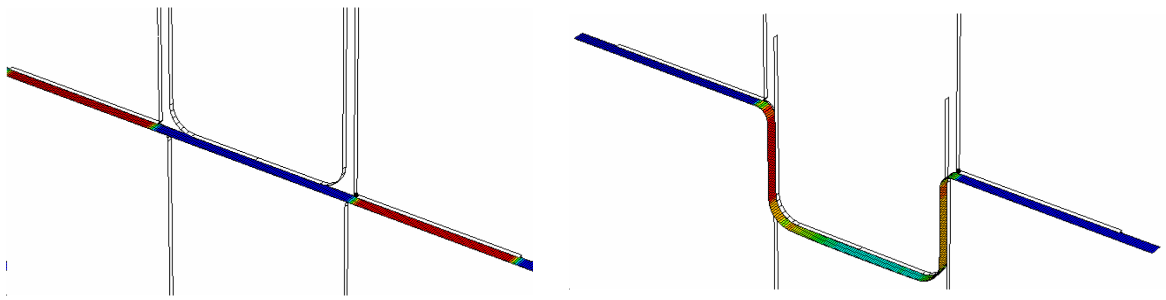

Figure 3. Geometrical model

As in the experimental tests, initially the welding line was place exactly on the central axis of the part. After that, the welding line was moved toward the FEPO steel area incrementing each time with 8.75 mm. The last simulation was made with a welding line displacement of 70 mm with respect to the central axis of the part, toward the part area made from FEPO steel, more E220 steel flows into the forming process. The influence of the welding line position on the parameters of springback is illustrated in figure 4.

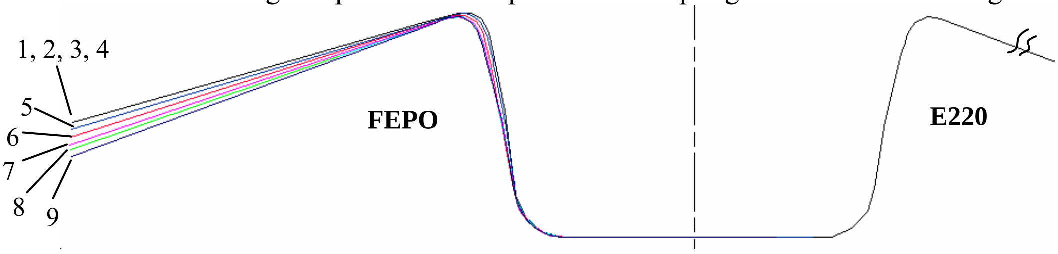

Figure 4. Influence of the welding line position on springback of tailor welded strips

The variations of springback parameters (θ_1, θ_2, ρ) as a function of the welding line position are graphically presented in figures no 5, 6 and 7 recorded in table 2.

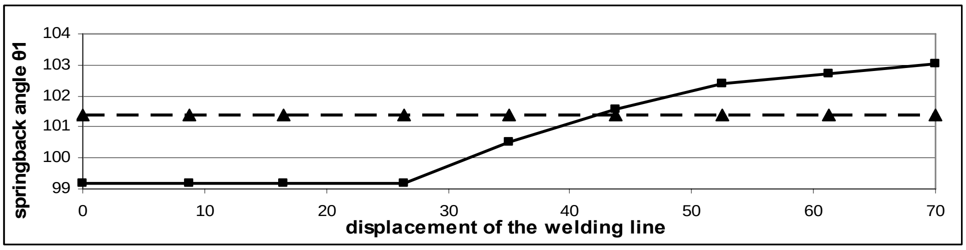

Figure 5. Variation of angle θ_1

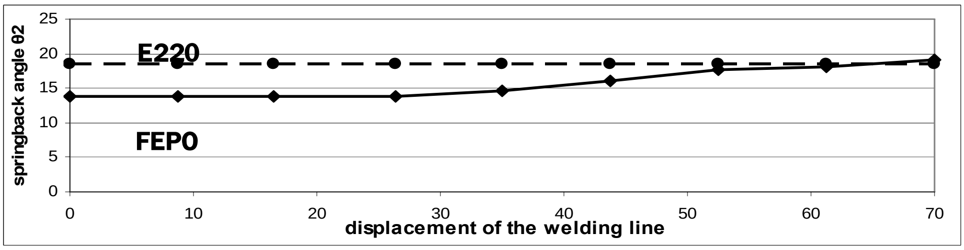

Figure 6. Variation of angle θ_2

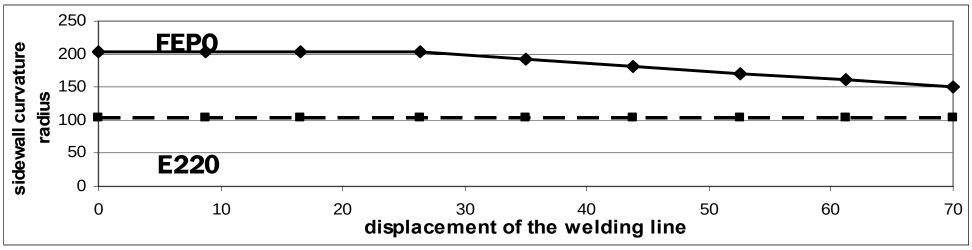

Figure7. Variation of sidewall curvature radius ρ

Table 2. Springback parameters

Welding line displacement [mm]	**Zone of the part made from FEPO steel**						**Zone of the part made from E220 steel**					
	Angle θ_1 [grd]		**Angle θ_2 [grd]**		**Sidewall Radius [mm]**		**Angle θ_1 [grd]**		**Angle θ_2 [grd]**		**Sidewall Radius [mm]**	
	Ideal	Measured	Ideal	Measured	Ideal	Measured	Ideal	Measured	Ideal	Measured	Ideal	Measured
0.00		99.20		13.80		203.93		101.4		18.4		103.34
8.75		99.20		13.80		203.93		101.4		18.4		103.34
16.5		99.20		13.80		203.93		101.4		18.4		103.34
26.25		99.20		13.80		203.93		101.4		18.4		103.34
35.00	90	100.51	0	14.68	∞	191.64	90	101.4	0	18.4	∞	103.34
43.75		101.56		16.15		182.15		101.4		18.4		103.34
52.50		102.39		17.62		170.17		101.4		18.4		103.34
61.25		102.72		18.14		160.86		101.4		18.4		103.34
70.00		103.03		19.06		151.05		101.4		18.4		103.34

4. CONCLUSION

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 (table 3). 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.

Table 3. Error between experimental and simulation results for the springback parameters

Welding line displacement [mm]	Zone of the part made from FEPO steel			Zone of the part made from E220 steel		
	Angle θ_1 [grd]	Angle θ_2 [grd]	Sidewall Radius [mm]	Angle θ_1 [grd]	Angle θ_2 [grd]	Sidewall Radius [mm]
0.00	-0.06	-0.16	-0.21	-0.09	0.03	-0.03
8.75	0.11	-0.13	0.03	-0.11	0.01	0.03
16.5	0.03	-0.01	-0.07	0.02	0.05	0.05
26.25	0.05	0.04	-0.09	0.05	0.03	0.00
35.00	0.24	-0.37	-0.05	-0.05	0.02	-0.02
43.75	-0.11	0.06	-0.07	-0.03	0.04	-0.01
52.50	0.14	0.00	0.04	0.01	0.01	0.00
61.25	0.09	0.23	-0.07	-0.01	-0.01	0.02
70.00	0.09	0.06	-0.05	0.02	-0.02	0.04

Analyzing the variations of springback parameters (θ_1, θ_2, ρ), obtained experimentally and by simulation, the following observation can be presented:

- positioning of the welding line on the bottom of the part has no influence on the springback parameters;
- placement of the welding line on the punch radius and on the part side wall determine an important grow of the springback parameters in the area of the part made from FEPO steel;
- displacement of the welding line cause insignificant variation of the springback parameters in the area of the part made from E220 steel.

5. REFERENCES

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