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SPRINGBACK IN AIR VEE BENDING PROCESS

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ABSTRACT
One of the most critical problems in air vee bending process is springback compensation to satisfy dimensional tolerances. Influence of tool geometry, bending angle and sheet thickness on springback in air vee bending was investigated in this paper. In order to evaluate influence of sheet material on springback, S355MC and DD13 steels were used in bending experiments. Experimental data showed that springback intensity of a material mostly depends on die width followed by sheet thickness and punch radius for all values of bending angles.
Keywords: air bending, bending experiments, springback

1. INTRODUCTION
Air bending is a flexible bending process where different bend angles can be achieved using the same tool set. A problem in air bending is that punch displacement for desired bend angle is very sensitive to variations in sheet thickness an mechanical properties of the material. But one of the most critical problem is the dimensional change of the deformed part after unloading caused by elastic recovery, also called springback. As a result, bend angles often are not accurate enough to satisfy required dimensional tolerances.

2. EXPERIMENTAL WORK
In order to study the influence of different tool parameters an experimental tool with adjustable die width and exchangeable punch radius has been built. In order to perform the air bending process the experimental tool was placed in the laboratory tensile test machine and V-shape products are made of sheets 80X40 mm, Figure 1

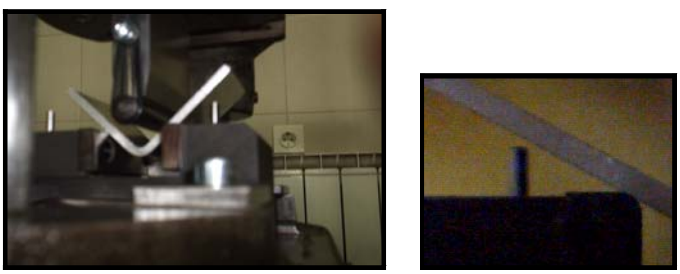

Figure 1. Experimental tool and digital photo of part angle during

Part angles before unloading were measured from the digital photos, while angles after elastic recovery were measured by “MarSurf XC 20” pertometer. Springback angle was determined by calculating the difference between part angles before and after unloading. The tool parameters values were chosen to satisfy common industrial practice, where ratio W_d/s generally varies between 5 and 10. Design variables and their levels for 3^2 factorial design with constant tool parameters are given in table 1.

Table 1. Overview of the tool parameters used in experiments

Constant parameters			Design variables				
Name		Value	Name		Min.	Aver.	Max.
Die width	Wd [mm]	25	Punch radius	Rp [mm]	3	4	5
Die radius	Rd [mm]	2	Bending angle	θ^0	90	105	120

3. RESULTS AND DISCUSSION

3.1. Deformation zones

A sheet under loading has three characteristic zones which defines a curvature between die shoulders: a wrap-around zone having an inner radius equal to the punch radius, two elasto-plastically deformed zones with variable bend radii and two elastically deformed zones. The widths of the zones and their curvatures during loading depend on tool geometry and ability of a material to work-hardening. The length between sheet-punch contact point and sheet-die contact point, so called „free bending length“(3), is a process oriented parameter that depends on die width, punch radius and sheet thickness. The free bending length value affects stress-strain state, thus influencing on springback.

3.2. Sheet material

In order to evaluate effect of sheet material on springback intensity $\Delta\theta^0$, bending experiments for two materials and sheet thickness s=4mm, according to parameters given in Table 1, were performed. First material is microalloyed hot rolled high strength steel S355MC EN and second one is non-alloyed hot rolled steel for cold plastic deformation DD13 EN. Figure 2 shows flow curves obtained by uniaxial tensile test, where more pronounced strain hardening effect for microalloyed steel compared to non-alloyed steel can be seen.

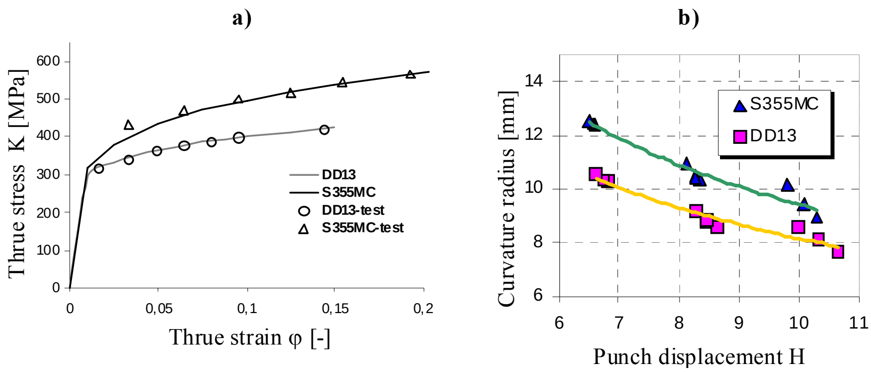

Figure 2. Flow curves for S355MC and DD13 steels a) curvature radii and punch displacement relations b)

Material S355MC with higher work-hardening (C=784,6 and n=0,195) has larger resistance to deformation and larger radii of the elasto-plastically deformed zone during bending compared to material DD13 (C=525,1 and n=0,130). Larger curvature in loaded state causes larger springback after

subsequent unloading. On the other hand, springback is a result of residual elastic stresses in sheet after deformation, which increases proportionally as the flow stress of material rises. Thus, material S355MC with comparatively larger flow stress has about 3 to 4 times larger springback for performed bending experiments.
The relations between outer bending radii after unloading and punch displacement is also shown in the figure 2b, where outer bending radii for material DD13 are smaller for about 15% to 20% at bending angles 90^0 and 120^0, respectively.

3.3. Punch radius and sheet thickness

Figure 3 shows effects of the punch radius (Rp) on intensity of the springback for two values of the sheet thicknesses and material S355MC. It can be found that increasing of the punch radius would also increase intensity of the springback for both values of sheet thicknesses. Effect of the punch radius becomes larger as the punch displacement increases and wrap-around zone becomes wider.

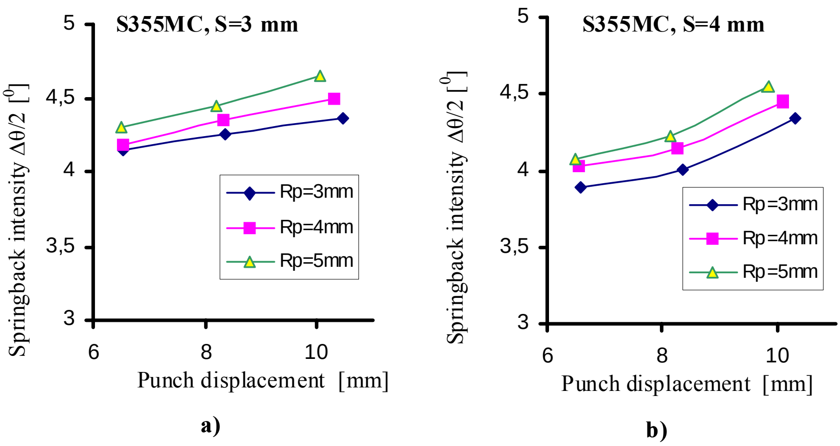

Figure 3: Springback intensity and punch displacement relations for

Thickness reduction from 3 mm to 4 mm causes average increase of the springback intensity for about 3,5% or 0.31^0. It is also observed that the effect of sheet thickness reduction weakens as punch displacement rises.

3.4. Die width

In a normal process maximum bending force will be reached at about 60% of the maximum punch displacement (1). However, when bending process was executed with a reduced die width a considerable increase of the punch force was obtained with maximum at the end of the punch displacement. The two values of the die widths – 20mm and 25 mm - were used in bending experiments for S355MC steel . In figure 4 b), it can be seen difference in the course and maximal values of the punch forces. It was observed that lowering the die width from 25 mm to 20 mm would increase maximum of the punch force for about 50% and remarkably change their course.
Figure 4 a) shows comparison of springback intensities for S355MC steel and design variables according to design matrix given in Table 1. The die width lowering causes conditions where significant amount of shearing over free bending length occurs and where realising the bent sheet is not only due to pure bending. Increased shearing changes stress-strain state as the die width lowers and thus affecting springback intensity, where decrease for about 3 times was observed.

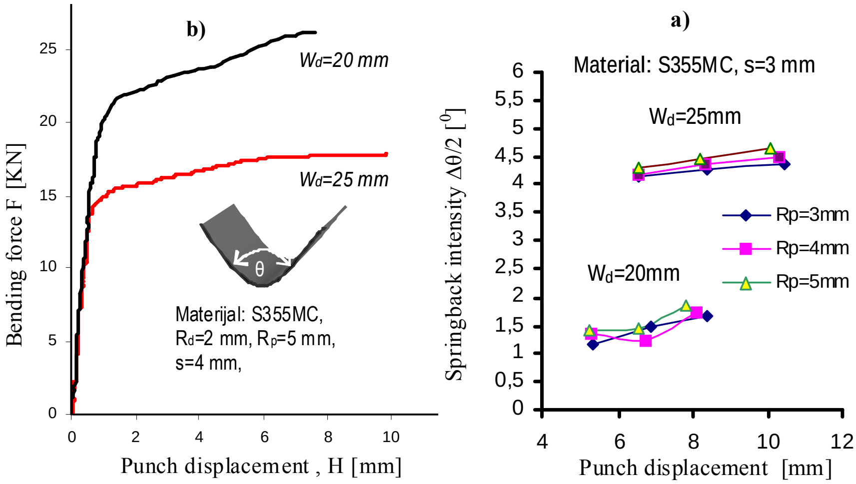

Figure 4: Springback intensity for reduced die widths a) Punch force course during bending b)

4. CONCLUSIONS

- Microalloyed S355MC steel has higher springback then non-alloyed DD13 steel due to comparatively higher flow stress, work hardening and elasticity limit.
- Lowering the punch radii from 5 mm to 3 mm decreases the springback intensity of S355MC steel for all values of sheet thicknesses and punch dispelacements. The punch radius decreasing causes reduction of warp-around zone curvature and thereby springback intensity.
- The die width reduction causes increased shearing of the free bending length thus affecting on springback intensity. Reducing the die width from 25 mm to 20 mm decreases springback intensity for about 3 times for microalloyed S355MC steel and punch radii 3,4 and 5 mm.

5. REFERENCES

[1] Vin, L.J. de; Streppel, A.H.; Lutters, D.; Kals, H.J.J, 1994, "A process model for air bending in CAPP applications", Singh, U.P.; et al (Edtrs): Sheet Metal 1994, Proc. of the 2nd Int. Conf. on Sheet Metal, April 13-13, Belfast, U.K., pp. 17-28.
[2] U.P. Singh, 1997, "Phisical modelling of air-bending process", sheet metal 1997, Proceedings of the 5th International Conference.
[3] A.H. Streppel; D. Lutters; E. ten Brinke; H.H. Pijlman; H.J.J. Kals, "Process modelling for air bending: equilibrium model and fem-simulation", Proceedings of the SheMet'99, Sept. 27-28, 1999, Erlangen-Nuremberg, Germany, pp.
[4] E.Šarić, „ Springback prediction in air bending process", PhD. Thesis, University of Tuzla, Mechanical faculty, Tuzla 2007.