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ANALYSIS OF SPRINGBACK IN THE CASE OF RECTANGULAR DRAWN PARTS MADE FROM ALUMINIUM ALLOY SHEETS

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Abstract: *The cold plastic drawing of metal sheets leads after the tools removing to an undesired phenomenon named springback. The springback generates the modification of the final part shape from its theoretical shape. In order to perform an accurate design of the forming process it is necessary to know and control this instability phenomenon. The present paper analyzes the influence of different factors on the springback parameters in the case of rectangular drawn parts made from aluminium sheets.*

Key words: *drawing process, springback, deviations rectangular parts, 3D scanning.*

¶

1. INTRODUCTION

The springback phenomenon considerably affects the accuracy of parts manufactured by cold plastic forming. The effect of springback is contrary to the effect of the forming loads and it is materialised by the difference between the desired shape of part and the obtained shape of part after the tools removing [1, 4]. The factors that influence the springback are as follows: material mechanical properties, material chemical composition, sheet thickness and working technological parameters [2, 3]. In the case of a given material, in order to control the springback, the technological parameters must be especially controlled [5].

The present paper analyzes the influence of different factors on the springback parameters in the case of rectangular drawn parts made from aluminium sheets. The analyzed factors of influence were as follows: the blankholder force and the drawing depth. The rectangular part was chosen because it has a complicated geometry and the springback presents some particularities. The analysis was made from experiment and the springback parameters were determined by using a 3D scanner ATOS.

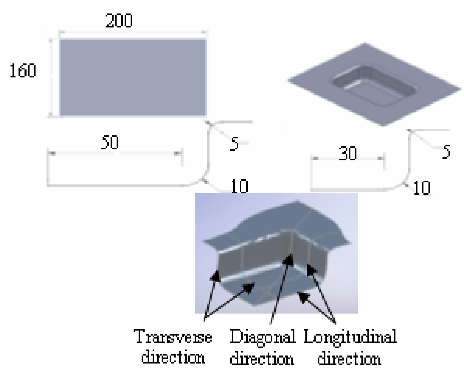

Fig.1. Part geometry and analyzed sections.

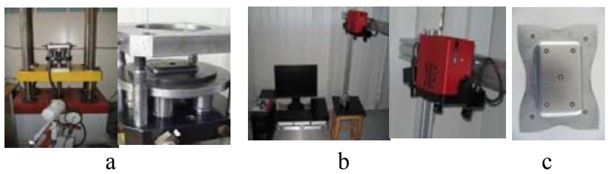

Fig. 2. Experimental equipment: *a* – mechanical press and die; *b* – 3D ATOS scanning system; *c* – parts with the applied markers.

2. THE METHODOLOGY OF THE SPRINGBACK DETERMINATION

2.1. Part geometry and analyzed springback parameters

The influence factors analyzed in the present study were the blankholder force and the drawing depth. The geometry of the drawn part and the chosen sections for determination of springback parameters are shown in Fig. 1.

2.2. The experimental equipment and conditions

The drawing process was performed by using an electro mechanical press where the control of blankholder force was made by using a hydraulic device (Fig 2a). The springback parameters were determined by using a 3D scanner ATOS and the ATOS Viewer software. The parts scanning were made by applying on parts special markers as reference points for the geometrical reconstructions of part on the basis of the ATOS Viewer software (Fig 2b, c). The experimental plan is presented in Table 1 and the material properties are given in Table 2.

2.3. Experimental results

2.3.1. Influence of blankholder force on springback parameters and deviations. The influence of blankholder force on springback parameters and deviations was studied for the following conditions: the drawing depth was maintained constant and the blankholder force was varied in four steps. The influences of blankholder force deviations from theoretical profile on the analyzed section are shown in Figs. 4, 5, and 6.

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Table 1

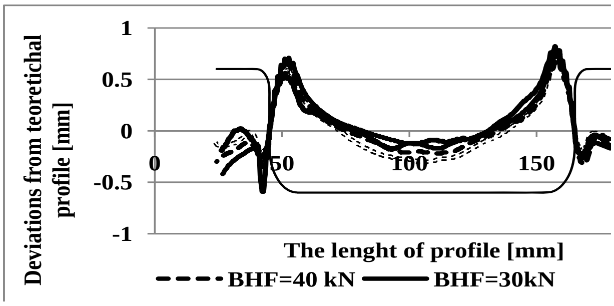
Experimental conditions

Drawing depth [mm]				**Blankholder force[kN]**				**Sheet thickness [mm]**
30				20	30	40	50	1
20	25	30	35	30				

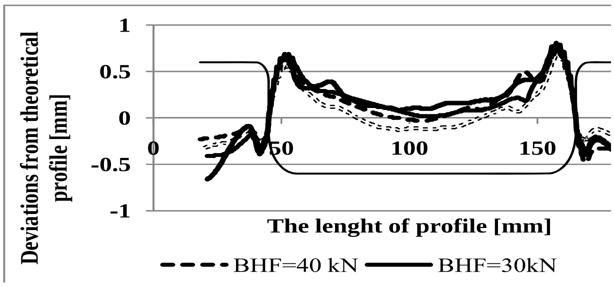
Table 2

Material parameters

Material	Young modulus E [MPa]	69739
Aluminium alloy 6061T4	Poisson coefficient μ	0.33
	Yield stress σ_y [MPa]	183
	Uniform elongation %	16.18
	Strength coefficient K [MPa]	460
	Normal anisotropy r	0.432
	Hardening exponent n	0.168

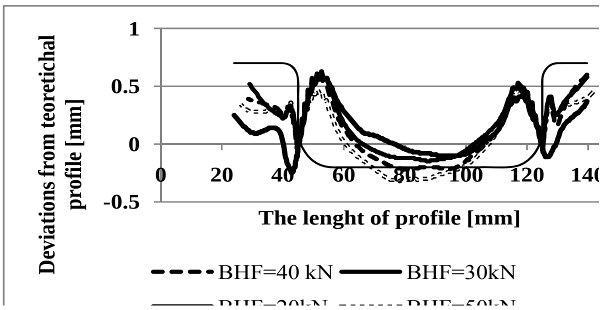


a – part middle

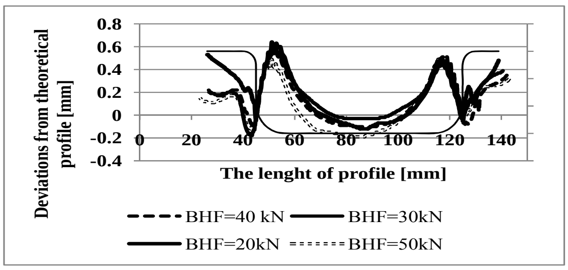


b – section at 20 mm from the part middle

Fig. 4. Deviations from theoretical profile on longitudinal sections.



a – part middle



b – section at 20 mm from the part middle

Fig. 5. Deviations from theoretical profile on transverse sections.

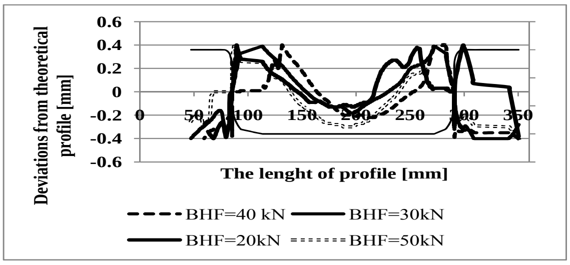


Fig. 6. Deviations from theoretical profile on diagonal sections.

Table 3

Longitudinal section – part middle

Zones	**Blank holder force [kN]** 20	30	40	50
flange [mm]	–0.19	–0.25	–0.13	–0.15
connection zone between flange and wall [mm]	–0.39	–0.27	–0.32	–0.24
connection zone between wall and bottom [mm]	0.69	0.745	0.66	0.66
bottom [mm]	–0.18	–0.17	–0.2	–0.31

section at 20 mm from **the part middle**

Zones	**Blank holder force [kN]** 20	30	40	50
flange [mm]	–0.53	–0.38	–0.27	–0.3
connection zone between flange and wall [mm]	–0.39	–0.33	–0.4	–0.24
connection zone between wall and bottom [mm]	0.73	0.75	0.70	0.645
bottom [mm]	0.1	0.02	–0.03	–0.12

Table 4

Transverse section – part middle

Zones	**Blank holder force [kN]** 20	30	40	50
flange [mm]	0.305	0.535	0.49	0.38
connection zone between flange and wall [mm]	–0.18	0.295	0.24	0.31
connection zone between wall and bottom [mm]	0.515	0.565	0.545	0.455
bottom [mm]	–0.1	–0.15	–0.21	–0.31

section at 20 mm from the part middle

Zones	**Blank holder force [kN]** 20	30	40	50
flange [mm]	0.53	0.2	0.2	0.13
connection zone between flange and wall [mm]	–0.24	–0.17	–0.07	–0.12
connection zone between wall and bottom [mm]	0.54	0.535	0.545	0.49
bottom [mm]	–0.12	–0.03	–0.1	–0.19

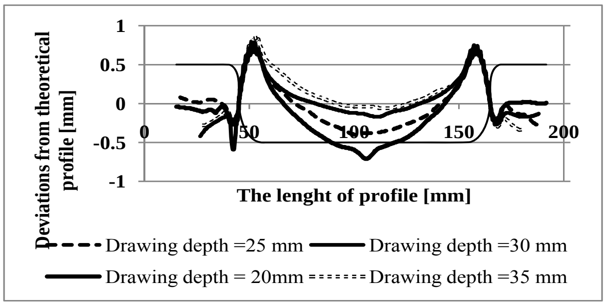
Table 5

Diagonal section

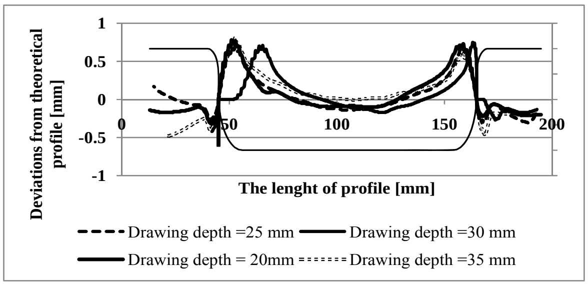
Zones	**Blank holder force [kN]** 20	30	40	50
flange [mm]	–0.39	–0.37	–0.37	–0.27
connection zone between flange and wall [mm]	–0.39	–0.33	–0.28	–0.10
connection zone between wall and bottom [mm]	0.385	0.38	0.39	0.39
bottom [mm]	–0.13	–0.18	–0.22	–0.3

The maximum deviations obtained in the case of rectangular drawn parts are registered as follows: in zone of flange, in zone of connection between flange and wall, in zone of connection between wall and bottom and in the bottom zone. The average of deviations in each zone was determined for all sections presented and centralised in the Tables 3, 4, and 5.

2.3.2 Influence of drawing depth on sections deviations. The influence of drawing depth on springback parameters was studied for the following conditions: the blankholder force was maintained constant and the drawing depth was varied in four steps. The influence of drawing depth on springback parameters in the case of longitudinal, transverse and diagonal sections are shown in Figs. 7, 8 and 9.

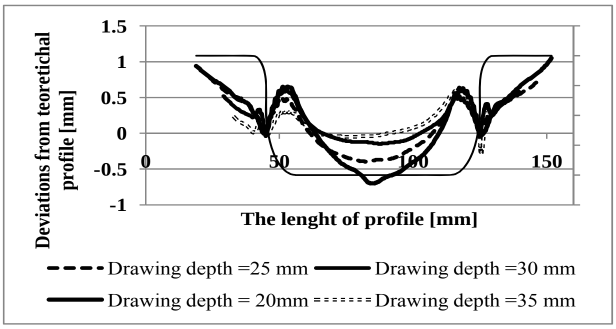


a – part middle

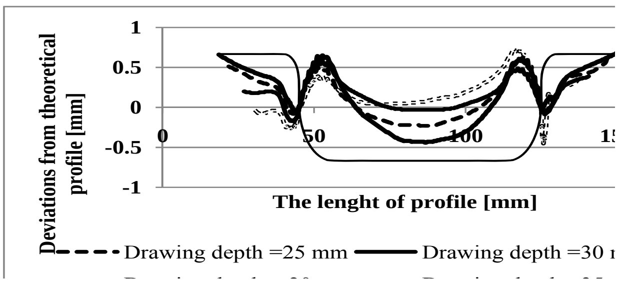


b – section at 20 mm from the part middle

Fig. 7. Deviations from theoretical profile on longitudinal sections.



a – part middle



b – section at 20 mm from the part middle

Fig. 8. Deviations from theoretical profile on transverse sections.

The average of deviations in each zone was determined for all sections presented and centralised in the Tables 6, 7 and 8.

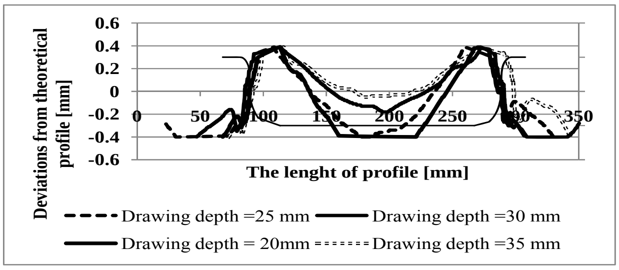


Fig. 9. Deviations from theoretical profile on diagonal sections.

Table 6

Longitudinal section
part middle

Zones	Drawing depth [mm]			
	20	25	30	35
flange [mm]	–0.01	0.13	–0.25	–0.37
connection zone between flange and wall [mm]	–0.2	–0.22	–0.27	–0.3
connection zone between wall and bottom [mm]	0.73	0.695	0.745	0.775
bottom [mm]	–0.71	–0.39	–0.17	–0.06

section at 20 mm from the part middle

Zones	Drawing depth [mm]			
	20	25	30	35
flange [mm]	–0.17	0.06	–0.38	–0.48
connection zone between flange and wall [mm]	–0.32	–0.26	–0.33	–0.4
connection zone between wall and bottom [mm]	0.755	0.69	0.75	0.87
bottom [mm]	–0.09	–0.14	0.02	0.01

Table 7

Transverse section
part middle

Zones	Drawing depth [mm]			
	20	25	30	35
flange [mm]	0.975	0.725	0.535	0.36
Connection zone between flange and wall [mm]	0.07	0.195	0.295	0.255
connection zone between wall and bottom [mm]	0.64	0.55	0.565	0.26
bottom [mm]	–0.7	–0.4	–0.15	–0.05

section at 20 mm from the part middle

Zones	Drawing depth [mm]			
	20	25	30	35
flange [mm]	0.66	0.565	0.2	0.13
connection zone between flange and wall [mm]	–0.05	–0.085	–0.17	–0.31
connection zone between wall and bottom [mm]	0.63	0.57	0.535	0.57
bottom [mm]	–0.44	–0.23	–0.03	0.04

Table 8

Diagonal section

Zones	Drawing depth [mm]			
	20	25	30	35
flange [mm]	–0.39	–0.39	–0.37	–0.39
connection zone between flange and wall [mm]	–0.29	–0.31	–0.33	–0.38
connection zone between wall and bottom [mm]	0.385	0.39	0.38	0.39
bottom [mm]	–0.4	–0.38	–0.18	–0.05

The analysis of the above presented results concerning the variation of part deviations from the theoretical profile presents the following aspects.

a. Influence of the blankholder force on part deviations:

- In the flange zone, for all sections, the deviations average tends to decrease to the increase of the blankholder forces.
- In the flange –wall connection zone, the average of deviations tends to decrease to the increase of blankholder forces for longitudinal and diagonal sections. The deviations of transverse middle section tends to increase to the increase of blankholder force, and the deviations of the transverse sections located at 20 mm from middle section, tends to decrease to the increase of blankholder force. In the wall –bottom connection zone, for all sections, the average of deviations tends to decrease to the increase of the blankholder forces.
- In the bottom zone, the increase of blank holder force leads to high values of the maximum deviations. Also, the bottom zone of part tends to make a curvature whose radius tends to increase to the increase of the blankholder force. The springback phenomenon leads to the increase of curvature radius of the bottom whose values are high if the blank holder forces are low.

b. Influence of the drawing depth on part deviations:

- In the flange zone, the average of deviations tends to increase to the increase of the drawing depth for longitudinal sections and to the decrease of the drawing depth for transverse sections; for the diagonal section, the average of deviations is less influenced by the drawing depth.
- In the flange – wall connection zone, for all sections, the average of deviations tends to increase to the increase of the drawing depth.
- In the wall –bottom connection zone, the average of deviations increases to the increase of the drawing depth for longitudinal sections, and decreases to the increase of the drawing depth for the transverse sections. The deviations on diagonal sections are less influenced by the drawing depth in this zone.
- In the bottom zone, the increase of drawing depth leads to the decrease of deviations. In the case when the drawing depth is high, the deformations on the bottom zone are high, the difference of deformations between the inner and outer faces is small and the deviations are also small.

3. CONCLUSIONS

The analysis of springback parameters variation and part deviations was performed for three directions (longitudinal, transverse and diagonal) and five part sections oriented in the before mentioned directions but having different locations.

In the case of high blankholder forces (50 kN), the deviations between real and theoretical profile are small in the case of longitudinal and diagonal sections and high in the case of transverse sections.

In the case of low drawing depth (20 mm), the deviations between the real and theoretical profile of part are small in the case of longitudinal and diagonal sections and high in the case of transverse sections; the deviations on the diagonal section are less influenced by the drawing depth.

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