Proceedings in Manufacturing Systems

Proceedings in Manufacturing Systems, Vol. 5 (2010), No. 1 ISSN 2067-9238

ANALYSIS OF THICKNESS VARIATION IN THE CASE OF CYLINDRICAL MICRO DRAWN PARTS MADE OF VERY THIN METAL SHEETS

Elena RADU-COSTACHE[1], Gheorghe BRABIE[2]

Abstract: *The micro deep drawing represents a cold forming process performed in order to realize micro parts. The main problems encountered in creating micro parts by micro drawing are as follows: the small thickness of material that can influence the drawing parameters and can affect the part quality; the small dimensions of parts that can influence the tools geometry and can create some problems in tools manufacturing; the instability phenomena (like: springback, wrinkling, necking, thickness variation etc.) that can affect the accuracy and quality of the produced micro-parts. The objective of the present work is to investigate and analyze an important instability and undesired phenomenon: thickness variation, phenomenon that can affect the springback intensity and the material integrity; the analysis was performed for the case of cylindrical drawn micro parts.*

Key words: *micro drawing; thin sheets; cylindrical micro-parts; thickness variation.*

1. INTRODUCTION

The micro drawing is a technology used to manufacture small metallic parts having at least two dimensions in the sub – millimetre range [1]. But, the micro drawing is not a simple technology because of its particularities and specific problems:

- small dimensions of the manufactured part, particularity that influences the tools geometry and can complicate the tools manufacturing [2];
- very small thickness of sheets, particularity that influences the drawing parameters, sheet behaviour during forming and can affect the part quality;
- micro drawing generates, like the macro drawing technology, different undesired phenomena (like: springback, wrinkling, necking, unfavourable residual stresses, thickness variation etc.) that directly affect the quality of the manufactured micro parts [3 and 4].

An important undesired phenomenon generated by micro drawing is represented by the variation of sheet thickness during forming; it is important because the differences in thickness along the part profile can create conditions for intensification of springback and also the reduction in thickness over certain limits can lead to the destruction of the material integrity. But, concerning this phenomenon many problems and especially the influence of different factors on micro drawing process and micro drawn parts quality are unknown. The present work presents some investigations by simulation concerning the thickness variation phenomenon generated by micro-drawing processes in the case of micro cylindrical parts.

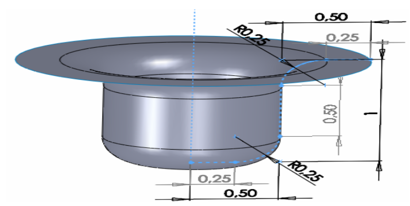
[1] PhD Student

[2] Prof., PhD, *E-mail: g-brabie@ub.ro*

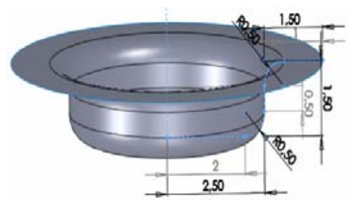
University of Bacău, Industrial Engineering Department, Calea Mărăşeşti, 157, 600115, Bacău, Romania

2. SIMULATION METHODOLOGY

The simulation was performed using the DYNAFORM software, version 5.7.1. The main objective of the simulation process was to obtain parts with parameters close to theoretical profile depending on material thickness. The simulations were made for sheets having thicknesses equal to 0.1 and 0.2 mm. The theoretical profiles of the parts used in simulation are shown in Figs. 1 and 2 and the main dimensions of the used tools are presented in Table 1.



$t = 0.1$ mm



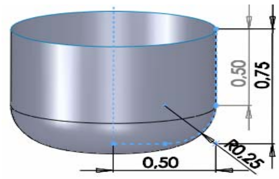
$t = 0.2$ mm

Fig. 1. Theoretic profiles used in simulation – part with flange.

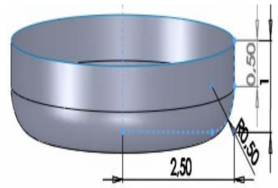
¶ *Table 1*

Tools parameters

Sheet thickness	Die connection radius (r_m)	Punch connection radius (r_p)	Die diameter (d_m)	Punch diameter (Dp)
(mm)				
0.1	0.25	0.25	1.2	1
0.2	0.5	0.5	5.4	5



t = 0.1 mm



t = 0.2 mm

Fig. 2. Theoretic profiles used in simulation – part without flange.

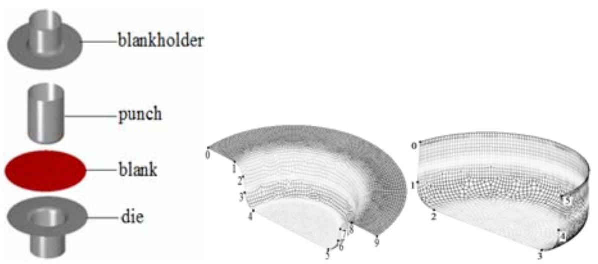
In simulation a tri-dimensional model was used, the blank was considered as deformable body and the die components were considered as rigid bodies (Fig. 3a). The *Transversely anisotropic elastic-plastic* criterion of plasticity was used and the stress-strain curve was implemented point to point. The part were made from an aluminium alloy having the Young modulus equal to 6.9×10^5 MPa and the density equal to 2.7×10^{-9} (t/mm^3). The material parameters and the working conditions are presented in Table 2.

In order to establish the variation of thickness along the parts profile in the case of cylindrical parts with flange, the following nine zones of part were analysed (Fig. 3b): zone 1 – flange part; zone 2 – connection between flange and wall; zone 3 – wall part; zone 4 – connection between wall and bottom; zone 5 – bottom part; zone 6 – connection between bottom and wall; zone 7 – wall part; zone 8 – connection between wall and flange; zone 9 – flange part. In the case of cylindrical parts without flange the following five zones were analysed (Fig. 3c): zone 1 – part wall; zone 2 – connection between wall and bottom; zone 3 – part bottom; zone 4 – connection between bottom and wall; zone 5 – part wall.

Table 2

Material parameters and working conditions used in simulation

Sheet thickness	Poisson ratio	Coefficient of anisotropy	Blank diameter		Drawing rate	Blank holder force
(mm)	–	–	(mm)		(mm/min)	(N)
0.1	0.3	0.658	3	2	0.1	25
0.2		0.56	10	6	0.2	80



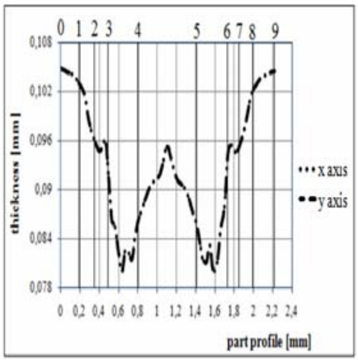
a – tools and blank b – part with flange c – part without flange
analyzed points of part profile

Fig. 3. Model used in simulation.

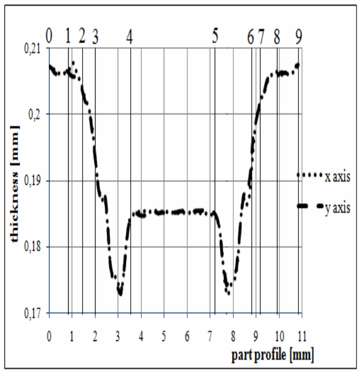
3. TEST RESULTS

3.1. Thickness variation in the case of cylindrical parts with flange

The diagrams of the sheet thickness variation along the part profile on the *OX* and OY axes for the two cases of sheet thickness are shown in Fig. 4 and the differences in sheet thickness along the part profile are presented in Table 3.



t = 0.1 mm



t = 0.2 mm

Fig. 4. Distribution of the sheet thickness variation along the part profile.

Table 3

Differences in thickness along profile part

Profile zone	Initial sheets thickness (mm)	Differences in thickness along part profile (mm)
part flange	0.1	+0.004
	0.2	+0.006
connection flange-wall	0.1	–0.001
	0.2	+0.004
part wall	0.1	–0.006
	0.2	–0.003
connection wall-bottom	0.1	–0.017
	0.2	–0.019
part bottom	0.1	–0.009
	0.2	–0.013
connection wall-bottom	0.1	–0.016
	0.2	–0.018
connection flange-wall	0.1	–0.005
	0.2	–0.002
part flange	0.1	–0.001
	0.2	+0.003
part flange	0.1	+0.039
	0.2	+0.006

The main conclusions resulted from the analysis of thickness variation, in the case of parts made from sheet having a thickness equal to 0.1 mm, are as follows:

- difference in thickness along the part profile in the zone of flange – delimited by the points 0 and 1 - is higher than in the zone of flange – delimited by the points 8 and 9;
- thickness variation along the part profile in the zone of connection wall - bottom delimited by the points 3 and 4 presents small differences by comparing with the zone of connection bottom – wall – delimited by the points 5 and 6;
- sheet thickness decreases in the zones of connection flange-wall from the point 1 to 2 and 8 and 7, respectively;
- sheet thickness decreases to the increase of drawing depth, in the sense from flange to bottom.

The main conclusions resulted from the analysis of thickness variation, in the case of parts made from sheet having a thickness equal to 0.2 mm, are as follows:

- thickness along the part profile in the zone of flange - delimited by the points 0 and 1 - is equal to the thickness in the zone of flange delimited by the points 8 and 9;
- thickness variation along the part profile in the zone of connection wall – bottom delimited by the points 3 and 4 presents small differences by comparing with the zone of connection bottom –wall delimited by the points 5 and 6;
- sheet thickness decreases in the zones of connection flange-wall from the point 1 to 2 and 8 and 7, respectively;
- sheet thickness decreases to the increase of part depth, in the sense from flange to bottom.

3.2. Thickness variation in the case of cylindrical parts without flange

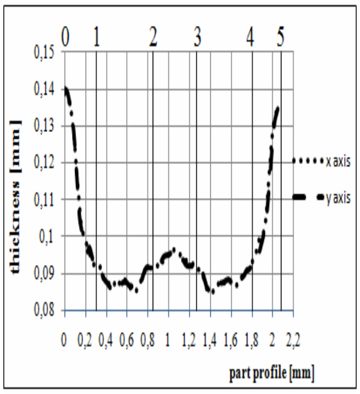
The diagrams of the sheet thickness variation along the part profile on the *OX* and *OY* axes for the two cases of sheet thickness are shown in Fig. 5 and the differences in sheet thickness along the part profile are presented in Table 4.

The main conclusions resulted from the analysis of thickness variation, in the case of parts without flange made from sheet having a thickness equal to 0.1 mm, are as follows:

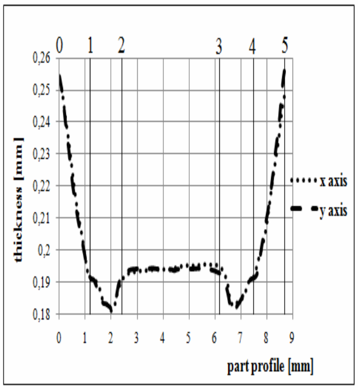
- difference in thickness along the part profile in the zone of wall - delimited by the points 0 and 1 - is higher than in the zone of wall – delimited by the points 4 and 5;
- thickness variation along the part profile in the zone of connection wall – bottom delimited by the points 1 and 2 is equal to the zone of connection bottom –wall delimited by the points 3 and 4;
- sheet thickness decreases to the increase of drawing depth, in the sense from wall to bottom.

The main conclusions resulted from the analysis of thickness variation, in the case of parts without flange made from sheet having a thickness equal to 0.2 mm, are as follows:

- difference in thickness along the part profile in the zone of wall delimited – by the points 0 and 1 – is higher than in the zone of wall delimited by the points 4 and 5;
- thickness variation along the part profile in the zone of connection wall – bottom delimited by the points 1 and 2 presents some differences by comparing with the zone of connection bottom – wall delimited by the points 3 and 4;
- sheet thickness decreases in the zones of connection wall – bottom delimited by the points 1 and 2 and 3 and 4, respectively;
- sheet thickness decreases to the increase of drawing depth, in the sense from wall to bottom.



t = 0.1 mm



t = 0.2 mm

Fig. 5. Distribution of the sheet thickness variation along the part profile.

Table 4

The differences of thickness along profile part

Profile zone	Initial sheets thickness (mm)	Differences in thickness along part profile (mm)
wall part	0.1	+0.010
	0.2	+0.021
connection wall-bottom	0.1	–0.012
	0.2	–0.014
part bottom	0.1	–0.007
	0.2	–0.006
connection wall-bottom	0.1	–0.012
	0.2	–0.012
wall part	0.1	–0.013
	0.2	+0.019

4. CONCLUSIONS

The main conclusions resulted from the analysis of the above presented results are as follows:

1. The micro drawing of cylindrical parts with and without flange, made from very thin sheets, is always accompanied by sheet thickness variation.

2. In the both cases, parts with and without flange, the sheet thickness decreases to the increase of part depth in the sense from flange to bottom for parts whit flange and in the sense from wall to bottom for parts without flange.

3. The utilization of thicker sheets leads to a smaller variation of thickness on the part bottom;

4. In the case of sheets having 0.1 mm thickness, the thickness variation between the zones of flange from the left and right sides presents some differences, but in the case of sheets having 0.2 mm thickness there are not differences between the same zones.

5. In the case of parts with flange, the sheet thickness increases by comparing to initial thickness of sheet in the zone of flange, where are developed compressive stresses; the decrease of sheet thickness by comparing to initial thickness of sheet takes place in the zones of part wall, part bottom and connection wall-bottom, where the drawing develops tensile and bending stresses.

6. In the case of parts without flange, the sheet thickness is higher by comparing to initial thickness of sheet in the zone of wall; the decrease of sheet thickness by comparing to initial thickness of sheet takes place in the zones of part bottom and connection wall-bottom, where the drawing develops tensile and bending stresses.

7. By comparing the similar zones of the part with flange and without flange, the differences in thickness are higher for parts with flange.

8. The variation of thickness along the part profile on the *OX* axes presents some differences by comparing to thickness variation on the *OY* axes; such differences are mainly caused by the material anisotropy.

REFERENCES

[1] U. Engel et al., *Micro forming – from basic research to its realization*, Journal of Materials Processing Technology, 125-126 (2002), pp. 35–44.

[2] Y. Saotome, T. Okamoto, *An in-situ incremental micro forming system for three-dimensional shell structures of foil materials*, Journal of Materials Processing Technology, 113 (2001), pp. 636–640.

[3] Cao J., *Fundamentals of Micro forming Processes*, Department of Mechanical Engineering Northwestern University, 2006.

[4] G. Brabie, *Specific phenomena during micro forming processes*, Optimum technologies, technologic systems and materials, TSTM, Vol. 12, No, 2 (2006), pp. 11–15.