ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume VI (XVI), 2007

INFLUENCE OF DIFFERENT FACTORS CONCERNING THE WRINKLING OF CYLINDRICAL DEEP-DRAWN PARTS

Carol SCHNAKOVSZKY, Bogdan GANEA
UNIVERSITY Of BACĂU
Research Center: Managerial and Technological Engineering
scarol@ub.ro; bogdan.ganea@ub.ro

Keywords: deep-drawing, wrinkling, plastic deformation
Abstract: The appearance of dimensional deviations of shape and position, of the defects in the metal sheets that have been subjected to a cold plastic deformation process (stamping, deep-drawing, forging, etc.), represents a critical problem for the specific industry, especially for the bulk production, like the machine manufacturing industry. The aim of this publication is to present the principal aspects that influence the wrinkling of cylindrical parts.

1. INTRODUCTION

Influence factors that lead to the wrinkling apparition are: the retaining force of the blank, the geometrical parameters of the die, the frictions that appear during deep-drawing between the blank and the work elements of the die, the material characteristics and anisotropy, the contact conditions, the part geometry, the mechanical properties of the material, the imperfections in the structure and the initial state of internal tensions of the material, etc.

Usually, the retaining force has to increase along with the increase of the deep-drawing depth, but we must take into consideration the fact that if its value is too big it can lead to cracks and even a break of the material. The main geometric parameters of the die which influence the wrinkling are: the diameter of the punch and of the active board, the active board and punch edge radiuses. In the case of friction between the piece and the tool, the increase of the coefficient of friction determines the wrinkling to reduce, but high values of the coefficient can cause cracks and material breakage.

The main phenomena of instability appearing at the cold forming of metal sheets, which lead to a decrease of the processing accuracy through the modification of the geometrical shape and the faulting of the machined surfaces, can be thus grouped:

- Phenomena of instability which appear after the process of plastic deformation and which lead the modification of the shape of the deformed parts after the deformation forces have stopped. The most important phenomenon of this kind is the phenomenon of elastic recovery;
- Phenomena of instability which appear during the process of deformation, compression instability being one of them.

2. THE STUDY OF FOLDING

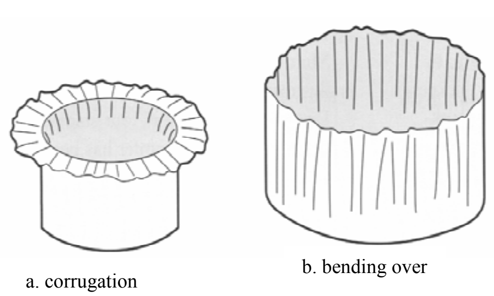

Fig. 1. Wrinkle types

The phenomenon of wrinkling is specific to the process of deep-drawing and, depending on the position in the piece in which it occurs, it can be:

- flange instability, also called wrinkling of the flange (corrugation), fig. 1,a;
- Instability in the body of the piece, also called wrinkling of the walls (bending over), fig. 1, b.

In the case of deep-drawing, under the effect of the deformation force, the blank will be subjected to a tangential compression stress and a radial extension stress. For example, in the case of the piece flange, although the radial extension stress of the flange is relatively high, the tangential compression stress can lead to the risk of its wrinkling, a risk which is very likely to appear when the difference between the outer diameters of the blank and the finished piece is big and the sheet thickness is small.

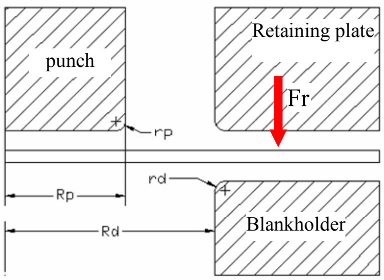

Fig. 2. Deep-drawing diagram

To accomplish experimental tests it was used a die according with the design (fig. 2). The geometrical parameters have the following values:

- die radius: R_d = 40 mm;
- die edge radius: r_d = 7,5 mm;
- punch radius: R_p = 38,2 mm;
- punch edge radius: r_p = 8 mm;

The shape of the obtained parts and the wrinkling variation depending of the retaining force are presented in fig. 3.

Initially, the metal sheet used is a disc having 150 mm in diameter and the thickness of 1 mm. The material used is a carbon steel with a high degree of deformability DC05 having the following characteristics:

- Young modulus E= 191 GPa;
- Poisson's ratio 0,34;
- Flow stress is 187 MPa;
- Strain hardness coefficient n = 0,189;
- Maximum limit strength 299 MPa.

2.1. THE INFLUENCE OF THE RETAINING FORCE AND THE DEEP-DRAWING DEPTH ON THE WRINKLING APPEARANCE

The study on the influence of the retaining force *Fr* over wrinkling has been made using dies that work according to the figure 2. There were measured the values of the retaining forces as well as the height of the wrinkle, depending on the deep-drawing depth.

The deep-drawing speed was 18 mm/min, the deep-drawing depth varying between 10 and 40 mm.

Fig.3. Variation of the wrinkles depending on the retaining force

The numerical values from the experiments are presented in the following table. Also, the graphical representation of these values is shown in figure 4.

Deep-drawing depth	**mm**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
Wrinkle height (mm)	F_r=20 KN	0,6	0,9	1,4	2,3	4	5,5	6
	F_r=80 KN	0,5	0,8	1,2	1,8	2,1	2,8	3,2
	F_r=150 KN	0,45	0,6	0,65				
	F_r=200KN	0,2	0,5	0,6				

The wrinkle amplitude measurement has been realized on a perpendicular section on the part axis situated at the middle of the height. Because the formed wrinkles for a given part don't have the same amplitude, the values presented here describe the maximum limit of those measured. The chart from figure 4 shows that the wrinkle height decreases with the increase of the retaining force, but over a certain value the cracking and braking of the material occur. We can observe this fact especially on the retaining forces that have 150 and 200 KN.

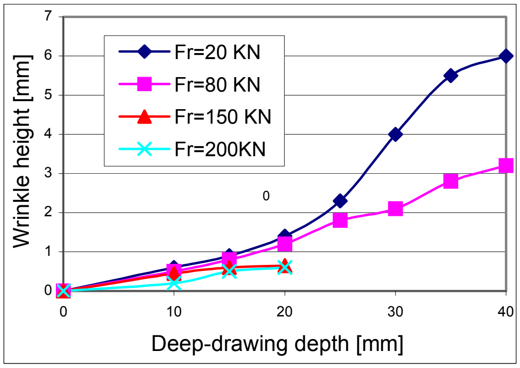

Fig. 4 Dependency between wrinkle height and the deep-drawing depth

The increase of the retaining force must be made up to an optimal value, after which the effect is negligible. Also, this chart shows that the wrinkle height increases along with the deep-drawing depth.

2.2. THE INFLUENCE OF THE DIE AND PUNCH EDGE RADIUS ON THE WRINKLING APPEARANCE

From the experimental study, figure 5, it was observed that for deep-drawing depth greater than 30 mm, the wrinkle height increases for small edge radiuses, whilst for smaller deep-drawing depth, the wrinkles have grater amplitude for grater edge radiuses. Like the die, it is indicated not to use small values of the punch edge radius because these can lead to braking of the material.

Deep-drawing depth	mm	10	15	20	25	30	35	40
Wrinkle height (mm)	r_p = 2	0.5	0.9	1.4	2.1			
	r_p = 5	0.5	0.9	1.4	2	2.3		
	r_p = 8	0.5	0.8	1.2	1.8	2.1	2.8	3.2
	r_p = 10	0.5	0.8	1.2	1.6	1.9	2.5	2.8

- r_p is the punch edge radius
- The experimental values are for F_r = 80 KN

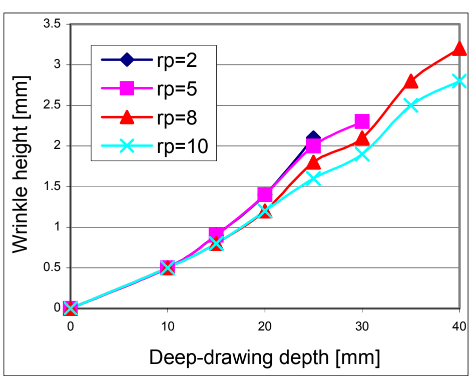

Fig. 5 Dependency between the edge radius and the wrinkle height

Also it can be observed that the wrinkles amplitude formed unto the end of the deep-drawing process decreases along with the die edge radius. This tendency isn't obvious at the beginning of the deep-drawing process because for smaller edge radiuses it is developed high amplitude wrinkles.

2.3. THE INFLUENCE OF FRICTION ON THE WRINKLING APPEARANCE

For this study several experiments have been performed for coefficient of friction in value of 0.01; 0.05; 0.1, a punch edge radius r_p = 8 mm and a retaining force F_r = 80 KN. The results are presented in figure 6.

Deep-drawing depth	mm	10	15	20	25	30	35	40
Wrinkle height (mm)	μ = 0.01	0.5	0.9	1.5	2.5	2.8	3	3.3
	μ = 0.05	0.5	0.8	1.2	1.8	2.1	2.8	3.2
	μ = 0.1	0.2	0.3	0.4				

It was observed that if the friction forces are low, the wrinkling is more pronounced, but if the friction forces are too high the material can break. For this matter, the friction in the die is a very important parameter that needs to be optimized depending of the die construction, the part geometry and the retaining force.

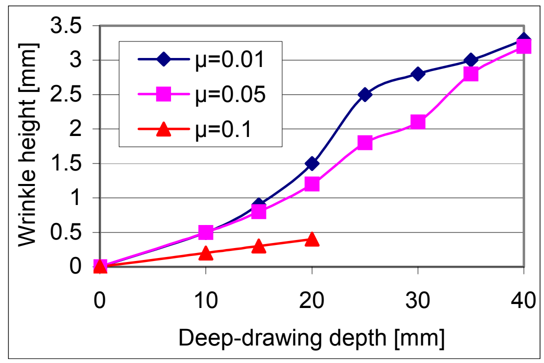

Fig. 6 Friction influence

3. CONCLUSIONS

In conclusion, the height of the wrinkles is reduced by increasing the retaining force, decreasing friction, increasing the tools edge radius and reducing deep-drawing depth all together in one operation. Concerning friction, the reduction of coefficient of friction has to be made up to a certain limit that won't lead to material breakage. Reducing the coefficient of friction down to the minimal value has a contradictory influence for the desired propose.

REFERENCES

1. T. Balun, P. Ling, M.M.K. Lou, S.C. Tang, DETECTION AND ELIMINATION OF WRINKLES ON AN AUTO-BODY PANEL BY THE BINDER SET ANALYSIS, SAE Tech. Pap. Series 930515, 1993.

2. J. Cao, M.C. Boyce, WRINKLING BEHAVIOR OF RECTANGULAR PLATES UNDER LATERAL CONSTRAINT, Int. J. Structures 34 (2), pp 153-176, 1997.