

Effect of Various Parameters on the Wrinkling In Deep Drawing Cylindrical Cups

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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 (deep-drawing), represents a critical problem for the specific industry, especially for the mass production, like the machine manufacturing industry. The aim of this publication is to present the principal aspects that effect of various factors like BHF, punch radius, die edge radius, and coefficient of friction on the wrinkling of cylindrical parts in deep drawing process. The initiation and growth of wrinkles are influenced by many factors such as stress ratios, the mechanical properties of the sheet material, the geometry of the work piece, and contact condition. It is difficult to analyze wrinkling initiation and growth while considering all the factors because the effects of the factors are very complex and studies of wrinkling behavior may show a wide scattering of data even for small deviations in factors. In the present study, the mechanism of wrinkling initiation and growth in the cylindrical cup deep drawing process is investigated in detail.

Keywords: Deep-Drawing, Wrinkling, Plastic deformation, Blank Holding Force.

1. Introduction

Effect of various factors that lead to the wrinkling apparition are: the blank holding 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 blank holding 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 [1] are: the diameter of the punch 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 [12].

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.

The force exerted by the blank holder on the sheet supplies a blank holding force which controls the metal flow. This restraining action is largely applied through friction. Excessive flow may lead to wrinkles [2] within the part.

Phenomena of instability which appear during the process of deformation, compression instability being one of them. Wrinkling defect generally occurs at the flange and is generated by excessive compressive stress that causes the sheet to buckle.

Wrinkling and tearing or rupture thus define the deep drawing process limits [8-

10]. For this problem, many variables affect the deep drawing process, these include material properties, die design, friction conditions, drawing ratio and BHF, punch corner radius, punch speed etc. A properly chosen BHF can prevent wrinkling [7].

1.1 Research Objective

The main objective of the proposed research paper is to eliminate the various defects like wrinkling [4], thinning and tearing in deep drawing process to produce a cylindrical cup of required shape and size. For general deep drawing, operations, most people define the defects as that blank which can be deformed into a cylindrical cup with either a uniform flange or cup free from ears.

However it is not easy to an eliminate the defects because of complexity of deformation behavior and there are couple of process parameters like die radius, punch radius, punch speed BHF and amount of friction which affects the result of the process, i.e., tearing, wrinkling and thinning. Even a slight variation in one of these parameters can result in defects [5].

2. Experimental work

A set of deep drawing experimental facilities were designed to analyze formability of the EDD steel alloy sheets. The arrangement tool dies setup is shown in fig. No. 1. The deep drawing experiments were carried out using the double action hydraulic press with the capacity of 200 ton made of Bemco Hydraulics limited at Pennar Industries Limited, Hyderabad. Materials used in the experiments are EDD alloy sheets. The initial diameters of blanks are 164.5 mm and 166 mm with a sheet thickness 5 mm and 3.65mm respectively. Process parameters include the speed, lubricant of tools such as Coconut oil or white dramate coolant oil which was uniformly spread over the surfaces of tools and blank. Polythene paper is placed at top of blank for improving the life of the punch and die.

The ram speed of the press was 600 mm/min. in forward stroke and 8100 mm/min in return stroke. The size of the table and ram plate was 1000mm x 1000mm. The ram plate had the maximum stroke distance 150 mm. The maximum working pressure of the pressure was 500 KN/mm² with motor capacity of 20 h.p.

The punch and die is made of high carbon high chromium steel and a radius of 4mm and 10mm respectively. The die block was made from oil hardened D2 steels or HCHCR steels. The outer and inner diameters of the die block were taken as 250 mm and 102.2 mm respectively. Thickness of the die block is 40 mm.

To produce a cylindrical cup of 112.4mm diameter and 42.5mm height from a flat sheet of 164.5mm diameter of blank and 5mm of thickness. The required tools like die, punch, blank holder and clamping devices were designed and fabricated to suit the hydraulic press specifications. The drawing force required to convert the blank of diameter 164.5mm with thickness 5 mm into a cylindrical shape of cup was 9.0 ton [4]. Additional force 20 to 40% was added to take into account the rapid change in the structure.

Then blank was etched by OLEPHOS-XL and Tonato crystal white powder in 15 to 20 minutes and then quenching is done by air cooling. After etching clean the blank with wood flour. The clamping pressure is applied by means of a hydraulic die cushion. Die cushion pressure can be keep constant (120 KN/mm²) or varied as a function of stroke, with a maximum load of 100 tons.

The experimental setup of the cylindrical cup is shown in fig no. 1.

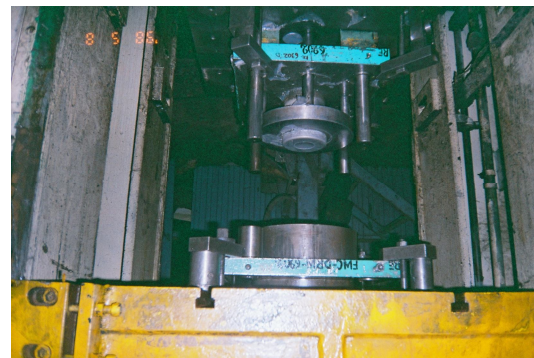


Fig.No.1. Experimental set up

The tooling setup is arranged in hydraulic press to measure the loads and stroke during the deformation. The punch load or force is measured with the help of an load cell. The Blank Holder plate is supported by 8 cushion pins which are transfer the load from the die cushion to the Blank Holder supporting plate.

The BHF was measured by providing load cells at sides of the cylindrical Blank Holder.

The chemical composition is shown in Table.1.

Table.1. Chemical composition of EDD steel alloy

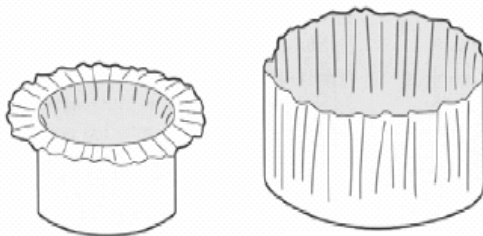
C	Mn	S	P	Al	Si
0.080	0.400	0.050	0.030	0.033	0.019

3. Wrinkling

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) [11] is as shown in fig. No.2 (a).
- Instability in the body of the piece, also called wrinkling of the walls (bending over) is as shown in fig. No. 2(b).

This type of defect usually occurs on the flange at the sides (flange wrinkling). The BHF is sides of wall (side wrinkling). The BHF is concentrated on the corners, where the metal thickness more, the sides of the cup cannot get enough pressure to restrain the metal and prevent wrinkling. Increasing the blank holder pressure at the sides of the circular blank using multipoint pressurized control systems is to improve the formability and drawability of cylindrical cups.



(a). Flange wrinkling b).Side wrinkling

Fig. No.2. Types of Wrinkles

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 [6].

To accomplish experimental tests it was used a die according with the design is as shown in fig. No. 3.

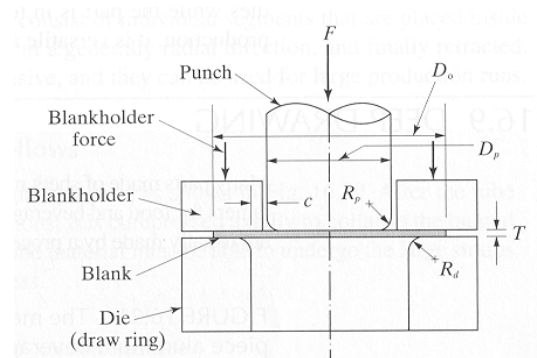


Fig. No. 3. Deep drawing diagram

The geometrical parameters have the following values:

- die radius, $R_d = 90$ mm;
- die edge radius, $r_d = 23$ mm;
- punch radius, $R_p = 51.5$ mm;
- punch edge radius, $r_p = 3$ mm;
- Clearance, $c = 10$ mm

The shape of the obtained parts and the wrinkling variation depending of the retaining force are presented in fig. No. 4.



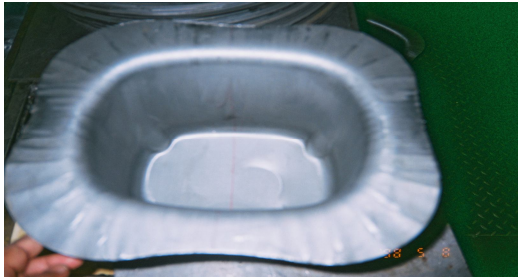


Fig. No. 4. Wrinkling variations

Initially, the metal sheet used is a disc having 164.5 mm in diameter and the thickness of 5 mm. The material used is a carbon steel with a high degree of deformability of Extra Deep Draw (EDD) having the following characteristics:

- Young modulus E = 245 KN/mm² ;
- Poisson's ratio = 0.34;
- Flow stress = 185 KN/mm²;
- Strain hardening coefficient n = 0,189;
- Ultimate Tensile Strength = 301.3 KN/mm²
- Elongation = 43 mm
- Hardness =49 RB/VBN

From these results of the optimized cup, some relations are reduced for the intercept (V_0) and slope (V_1) of the BHF function.

There is a general trend for the slope to increase with increasing the drawing ratio in a linear manner. Thus, it is possible to reduce a general linear relation between the drawing ratio (B_0) and the BHF function slope (V_1) for all coefficient of friction.

Also, a second linear relation between the drawing ratio and the BHF function intercept (V_0) is observed.

Design variables:

1. Initial value of the BHF function (V_0)
2. Slope of the BHF function (V_1) (Either positive or negative slope)

$$\therefore F_{BH} = V_0 + V_1L - (2)$$

Where, V_0 = Initial value of the BHF functions
 V_1 = Slope of the BHF function
 L =Punch travel.

There is a tendency for the intercept value to decrease with the increase in the drawing ratio. From those two linear relations and the BHF equation a general relation between the BHF and the drawing ratio and the punch travel can be conducted as follows.

$$F_{BH} = 68.544 - 29.660 B_0 - 8.143L + 4.189 B_0L$$

Avoid wrinkling at each punch travel (L) increment.

The following relations must be satisfied.

$$F_{BH} > F_{\text{wrinkling}}$$

3.1. The effect of the blank holding force and the deep drawing depth on the wrinkling appearance

The study on the influence of the blank holding force over wrinkling has been made using dies that work according to the figure 5. There were measured the values of the blank holding forces as well as the height of the wrinkle, depending on the deep-drawing depth.

The deep-drawing speed was 20 mm/sec, the deep-drawing depth varying between 10 and 45 mm.

The numerical values from the experiments are presented in the following table no.2. Also, the graphical representation of these values is shown in figure no.5.

Table no.2: The experimental values of the blank holding force and the deep drawing depth on the wrinkling appearance

Deep drawing depth	mm	10	15	20	25	30	35	40	45
Wrinkling height(mm)	Bhf=40KN	1.1	1.4	1.9	2.8	4.3	6.4	6.7	6.9
	Bhf=80KN	1.0	1.3	1.7	2.3	2.5	2.8	3.5	3.8
	Bhf=140KN	0.8	1.0	1.1	1.2	1.4			
	Bhf=200KN	0.3	0.5	0.6	0.65	0.69			

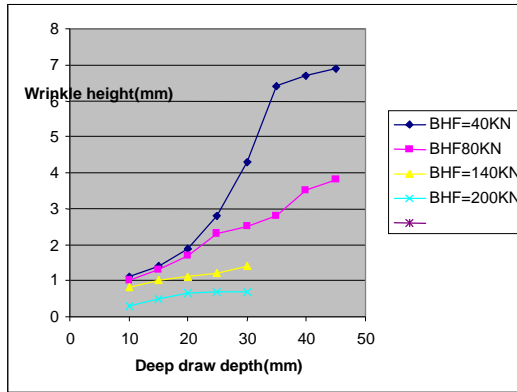


Fig.no.5. The Effect of the Blank Holding Force and the Deep Drawing Depth on the Wrinkling

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 no. 5 shows that the wrinkle height decreases with the increase of the blank holding force, but over a certain value the cracking and braking of the material occur. We can observe this fact especially on the blank holding forces that have 140 and 200 KN. The increase of the blank holding 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.

3.2. The influence of the die edge radius and punch edge radius on the wrinkling

From the experimental study, figure no.6, it was observed that for deep-drawing depth greater than 40 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 is shown in table no.3.

Table no.3: The experimental values of the die and punch edge radius on the wrinkling

Deep drawing depth	mm	10	15	20	25	30	35	40	45
Wrinkling height(mm)	rp=3	0.6	0.8	1.5	2.3	2.35			
	rp=6	0.65	0.85	1.5	2.1	2.4	2.6		
	rp=8	0.65	0.8	1.3	1.9	2.3	2.8	3.5	3.9
	rp=10	0.65	0.8	1.3	1.8	2.1	2.4	3.1	3.3

- rp is the punch edge radius
- The experimental values are for BHF = 70 KN

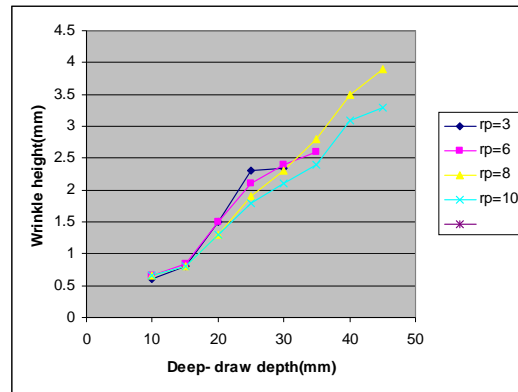


Fig.no.6. The Influence of the Die and Punch Edge Radius on the Wrinkling

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.

3.3. The effect of friction on the wrinkling height

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 rp = 8 mm and a blank holding force = 70 KN.

Table no.4: The effect of coefficient of friction on the wrinkling height

Deep drawing depth	mm	10	15	20	25	30	35	40	45
Wrinkling height(mm)	$\mu=0.01$	0.8	1.1	1.7	2.8	3.2	3.5	3.7	4.1
	$\mu=0.05$	0.75	1.0	1.5	2.5	2.9	3.4	3.5	4.0
	$\mu=0.1$	0.4	0.6	0.81.0					

The experimental values and results are presented in table no.4 and figure No.7 respectively.

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 blank holding force.

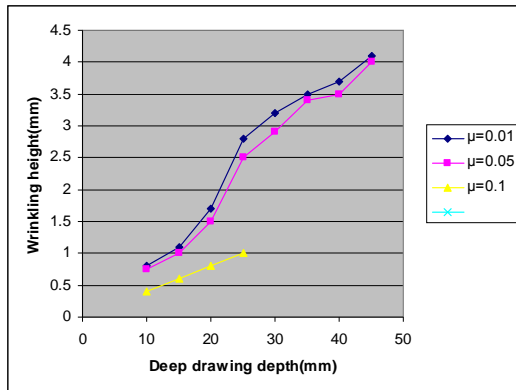


Fig.no.7. The Effect of Friction on the Wrinkling Height

4. Conclusions In conclusion, the height of the wrinkles is reduced by increasing the blank holding 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.

The defect of wrinkling occurs easily in this process of EDD steel alloy sheets. It is to avoid wrinkling of blank by selecting the correct BHF's, decreasing friction, increasing the tool edge radius and reducing the deep drawing depth all together in one operation.

Acknowledgements

The authors express their thanks to the management of Pennar Industries Limited, Hyderabad. I would like to express my deepest gratitude to my advisers for encourage to write the paper.

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