The effect of blank holder on the deep drawing process on plates using software based with a Finite Element Method (FEM)

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Abstract. To reduce product defects in the deep drawing plate process, the manufacturing industry needs to design a product design in the form of initial simulations so as to reduce losses due to design errors. The purpose of this study was to determine the effect of blank holder characteristics on the plates produced in the deep drawing process. The effect of blank holder includes three factors, including: deep drawing without using the holder, clearance, and draw ratio. The simulation in this study uses the Finite Element Method (FEM) method with the help of a computer. The provisions of the part in this simulation with an approximate size setting of 0.25, the material used is steel with a thickness of 0.5 mm and a blank diameter of 51 mm. Cylinder cup diameter 40 mm and depth of formation process 60 mm radius 8 mm and punch force 550 N. Based on the simulation results from the deep drawing process without using blank holders, the force needed for the drawing process will be even greater. While the clearance variable will reduce the force required during the drawing process. And the draw ratio variable gets smaller and will require greater force.

1. Introduction

In the deep drawing process, maximization of efficiency and minimization of errors is the very important parameters. Deep drawing technique is a very complex, costly and widely used manufacturing process, in many industrial applications [1]. In the process of defective Deep drawing on the product it is impossible to avoid, one of the efforts in minimizing defects is to conduct trial and error experiments on each product design to be produced. This process depends on one's expertise and experience resulting in inefficient time, cost and energy. To reduce product defects in the deep drawing plate process, the manufacturing industry needs to have product design planning in the form of initial simulations so that it can reduce losses due to design errors.

According to the German standard DIN standard, DIN 8584, Deep drawing is defined as “a tensile/compressive sheet forming process in which a plane blank is formed into a hollow part open on one side (direct drawing) or an open hollow part is formed into another hollow part with a smaller cross-section (re-drawing)” [2].

From previous FEA work and the experimental work performed to date, it seems that the punch/die radii have the greatest effect on the thickness of the deformed mild steel cups compared to blank-holder
force or friction [3]. The smaller is the punch/die radius, the greater is the punch force and shorter is the final draw. It has also been observed from the work to date that the speed of drawing plays an interesting role, in so far as, the higher is the speed the further is the draw, which is not entirely as expected. The cause of this will be further investigated. If the blank-holder force is not kept within the upper and lower limit of reasonable range it does have a significant effect on depth of draw, with the punch tearing through the bottom of the cup if the force is too high and if too low wrinkling of the flange area occurs [4].

Deep drawing is a common sheet metal forming process used to manufacture complicated 3-D parts from thin sheet metals. In many industries, Deep Drawing is a very important metal forming process. Deep drawing is complex deformation affected by the geometrical and process parameters. Deep drawing process optimization is a challenging task. This paper presents a review on the deep drawing parameters and identifies directions for future research and the results of present study were showing the successfully produced aluminum alloys cup [5].

The material starts to flow in the die cavity when the stress exceeds, this is known as flow stress. Theoretically, the value of flow stress is investigated by the yield criterion which is a function of the maximum values of the stresses which is principle stresses in two perpendicular directions. And in a material residual stress is defined as stress without the action of external forces [6].

Based on the possible factors that cause defects in deep drawing products, the main problems in this paper are: 1) analyzing the influence of characteristics of holders that are influenced by blank thickness, clearance, and draw ratio factors in deep drawing product components, 2) how analyze parts of the deep drawing process so that an optimal die design will be created to reduce the percentage of disability. The objectives of this study are: 1) researchers influence holder, clearance and draw ratio on deep drawing products using simulation. 2) help solve the problems of deep drawing processes on parts produced so as to minimize defects in the product. Limitation of the problem from the results of this study is the analysis with numerical methods and finite element methods with ABAQUS software on thickness changes in deep drawing product components caused by die drawing factors. Provisions of an approximate size of 0.25, the material used in the production process uses steel with a thickness of 0.5 mm and a blank diameter of 51 mm. cylinder cup diameter of 40 mm and the depth of the process of forming 60 mm 8 mm radius in the 1000 N punch force.

2. Research method

Deep drawing is the process in which a sheet metal blank, is drawn in a hollow cavity, referred to as the die, using a normal force applied by the punch, to produce a hollow shell. A blank holder is used to control and guide the flow of the blank material through applying the blank holder force (BHF) [7].

Drawing is a sheet-metal-forming operation used to make cup-shaped, box-shaped, or other complex-curved and concave parts. It is performed by placing a piece of sheet metal over a die cavity and then pushing the metal into the opening with a punch, as in Figure 1. The blank must usually be held down flat against the die by a blank holder.

Common parts made by drawing include beverage cans, ammunition shells, sinks, cooking pots, and automobile body panels [8].
Figure 1. (a) Drawing of a cup shaped part: (1) start of operation before punch contacts work, and (2) near end of stroke; and (b) corresponding work part: (1) starting blank, and (2) drawn part. Symbols: c ¼ clearance, Db ¼ blank diameter, Dp ¼ punch diameter, Rd ¼ die corner radius, Rp ¼ punch corner radius, F ¼ drawing force, Fh ¼ holding force.

2.1. Engineering analysis of drawing

Measures of Drawing One of the measures of the severity of a deep drawing operation is the drawing ratio DR. This is most easily defined for a cylindrical shape as the ratio of blank diameter Db to punch diameter Dp. In equation form,

$$\frac{Dp}{Db} = DR$$

(1)

The drawing ratio provides an indication, albeit a crude one, of the severity of a given drawing operation. The greater the ratio, the more severe the operation. An approximate upper limit on the drawing ratio is a value of 2.0. The actual limiting value for a given operation depends on punch and die corner radii (Rp and Rd), friction conditions, depth of draw, and characteristics of the sheet metal (e.g., ductility, degree of directionality of strength properties in the metal) [8]. It is very closely related to drawing ratio. Consistent with the previous limit on DR (DR > 2.0), the value of reduction r should be less than 0.50. The drawing force required to perform a given operation can be estimated roughly by the formula:

$$F = \pi D_p t (TS) \left( \frac{Db}{Dp} - 0.7 \right)$$

(2)

Where F ¼ ¼ drawing force, N(lb); t ¼ original blank thickness, mm (in); TS ¼ tensile strength, MPa (lb/in²); and Db and Dp are the starting blank diameter and punch diameter, respectively, mm (in). The constant 0.7 is a correction factor to account for friction. Eq. (2) estimates the maximum force in the operation. The drawing force varies throughout the downward movement of the punch, usually reaching its maximum value at about one-third the length of the punch stroke.

The holding force is an important factor in a drawing operation. As a rough approximation, the holding pressure can be set at a value ¼ 0.015 of the yield strength of the sheet metal [9]. This value is then multiplied by that portion of the starting area of the blank that is to be held by the blank holder. In equation form,

$$F_h = 0.015Y \pi \left\{ D_b^2 - \left( D_p + 2.2t + 2R_d \right)^2 \right\}$$

(3)
Where $F_h$ is the holding force in drawing, N (lb); $Y$ is the yield strength of the sheet metal, MPa (lb/in²); $t$ is the starting stock thickness, mm (in); $R_d$ is the die corner radius, mm (in); and the other terms have been previously defined. The holding force is usually about one-third the drawing force [10].

2.2. Deep drawing parts

![Deep drawing parts diagram](image)

**Figure 2.** Components of a punch and die for a blanking operation [11].

3. Results of analysis and discussion

The results of the analysis of objects as a whole are as follows, where the area which has the greatest thickness is indicated by the colour red and the area that has the smallest thickness is indicated by the colour blue:

3.1. Deep drawing simulation without using holders with blank thickness variations

(a) Thickness 0.5 mm

(b) Thickness 0.8636 mm
Figure 3. Cont.

(c) Thickness 0.8128 mm, (d) Thickness 0.9144 mm

Figure 3. Deep drawing simulation results without holders with plate thickness variations.

The above simulation results visually indicate a defect that occurs in the form of wrinkles in the punch radius area with the die radius on the plate element due to the deflection of the force of the punch and reverse force as there is no holder holding the function to clamp the plate. But adding thickness to the plate will reduce wrinkles.

3.2. Deep Drawing Simulation with Variations in Clearance

(a), clearance 0.6 mm
(b) clearance 0.7 mm
The simulation results above are changes in clearance varied in the deep drawing process can be seen visually the effect on the depletion of material in the die radius area which is in contact with the punch radius. This is because the clearance is too small and the greater the clearance will reduce material thinning. Deep drawing simulation with variations in draw ratio.

Figure 5. Simulation results draw ratio with variations in reduction on.
The results of the draw ratio simulation show that the higher the draw ratio, the thinning of the material will be smaller, this is due to the greater allowance between the punch and the upper die.

3.3. Graphic change of deep drawing without using the holder

Figure 6. Graph of changes in deep drawing without using a holder.

Figure 7. Graph of analysis plate simulation with variation of clearance.

Figure 8. Graph of analysis of plate simulation with variations in draw ratio.
Graph 6 above shows the relationship between punch displacement and punch load which is influenced by plate thickness and the deep drawing process does not use a holder. It can be concluded that the thicker the plate will be stretched, the greater the force will be needed.

Graph 7 above shows the relationship between punch displacement and punch load which is influenced by the clearance factor. The greater the clearance, the smaller the force needed will be because the friction force between the plate and the punch and die gets smaller.

Graph 8 above shows the relationship between punch displacement and punch load which is influenced by the factor draw ratio by increasing the punch diameter. It is known that the larger the punch diameter, the more force will be needed for the material drawing process. Graph changes the thickness variation in deep drawing without using a holder, the thicker a material will require an even greater force. Graph of changes in value on the plate with variations in clearance, enlargement of the clearance factor will result in the smaller force required. Graph of changes in value on the plate with a draw ratio, the higher the draw ratio value, the greater the force will be obtained.

The deep drawing simulation results without holders with variations in plate thickness have been taken concluded that the thicker the holder is used, the smaller the defects or wrinkles that occur so that the conclusion by increasing the thickness of the holder will reduce wrinkle defects. Variations in clearance changes affect the depletion of the material so that from the test results it is necessary to set the clearance on the part of the radius by adding clearance the goal is to avoid thinning resulting in cracking. By calculating a smaller draw ratio, it results in a thinning of the material so that the arrangement of the distance between the punch and upper die needs to be set as small as possible to anticipate material thinning.

Furthermore, from the results of the graph of the punch displacement relationship and the displacement load, it is known that the force to press the punch depends on the larger diameter of the punch, the greater the force required, so that the punch size is minimally adjusted to dies and the distance between dies and punch also need to adjust the draw ratio as small as possible the purpose is to reduce thinning and reduce the compressive force.

4. Conclusion
From the description of this paper, it can be concluded as follows: there is wrinkling on the plate in the area that is in contact with the punch radius and die radius, this is due to the absence of a clamp that holds the plate so that the plate is pushed by the force of the punch. Changes in the clearance factor have the effect of reducing the material thinning process (ironing) in the punch radius area that is in contact with the radius dies. Simulation can be seen that the change in the draw ratio will result in thickening at the end of the plate, this is due to the greater gap between the diding punch and the dies wall.

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