Effect of the Location of Draw Bead and Its Profile in Cylindrical Cup Forming

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Abstract: The effect of draw bead on the production of cylindrical cup in deep drawing process three metal (aluminum, brass, steel). The draw bead is designed by Bezier curve's equation that play an important role in prevent occurrence of wrinkling especially with improved aluminum, because that’s only lubricant is passed with aluminum, when compared it with without draw bead, it is noticed that the maximum drawing force will increase due to lubricant. It can be concluded that in deep drawing with draw bead the wax has used us a lubricant, be better compared to without draw bead for AL, good agreement is evident between ANSYS(18) and experimental work. comparing between deep drawing with draw bead and without the energy required to complete drawn when using draw bead is more than without draw bead, The aims of this paper to predict the wrinkling and thinning (necking) and to study the influence of using draw bead on the thickness distribution along the cup, so the hoop strain distribution along the blank is more uniform for using draw bead and thickness strain with & without using draw bead, is about 0.17% in thinning for brass with it and 0.20% in thickening to steel without it.

| Symbol | Meaning | Unit |
|--------|---------|------|
| Al3n   | Aluminum,3mm/Min, Lithium Grease | - |
| Al3f   | Aluminum,3mm/Min, Food Machinery Grease | - |
| Al3w   | Aluminum,3mm/Min, Wax | - |
| Br3n   | Brass,3mm/Min, Lithium Grease | - |
| Br3f   | Brass,3mm/Min, Food Machinery Grease | - |
| Gal3n  | Galvanized Steel,3mm/Min, Lithium Grease | - |
| Gal3f  | Galvanized Steel,3mm/Min, Food Machinery Grease | - |

1. Introduction
The aim of the sheet metal forming process is to produce a satisfactory part by plastic deformation; failure is recognized as fracture or buckling. Under three major headings, it is useful to find sheet metal forming technology: 1. Process. 2. Material. 3. Tests. In deep drawing process the blank is clamped between the die and the blank holder. The blank holder is loaded by a blank holder force, which is necessary to prevent wrinkling and to control the material flow into the die cavity. The punch is pushed into the die cavity, simultaneously transferring its specific shape and the die to the blank, when a very high blank holder force is applied the deep drawing process becomes a stretching process. [1].

In sheet metal forming process many factors have to be considered such as drawing force, blank holder force, friction force etc. The energy source for this deformation may be a hydraulic press at one end of the scale, mechanical press, or a high – explosive charge at the other [2]. deep drawing is a process in which a blank or work piece is usually controlled by a pressure plate, forced into and/or through a die by means of a punch to form a hollow component in which the thickness is
substantially the same as that of the original material [3]. The draw beads are one of the most important parameter to control the material flow and thus the part quality in the sheet forming process. Alaa Dahham.,(2007)[4]is studied the design optimization of deep drawing process in manufacturing is proposed to control the final shape of the work piece after elastic spring back.

The manufacturing process design problem is formulated to minimize the difference between the shape of the desired work piece geometry and the final analysis. G.H.Bae et al., (2007) [5] is studied draw-bead is applied to control the material flow in a stamping process and improve the product quality by controlling the draw-bead restraining force (DBRF). Actual die design depends mostly on the trial-and-error method without calculating the optimum DBRF. A. Murali G., B. Gopal M. et al.,(2010)[6] is studied the quality of sheet metal part is secured by the material flow into the die cavity. Draw beads are often used in sheet metal forming to restrain the sheet from flowing freely into die cavity, finite element method was used to optimize the location of a circular and rectangular draw beads and analyses the strain and thickness variations during the cup drawing process. Mehmet Firat et al.,(2010), [7] is studied a draw bead modelling technique is presented to improve the accuracy of finite element simulations in terms of part draw-in and thickness predictions and validated with channel drawing experiments of a high-strength low-alloy steel. The aim our work:

1. Design of manufacturing die with draw bead.
2. Location of the best position and size of the draw bead using Bezier curve.
3. Analyse the deep drawn with draw bead by ANSYS software.

2. Design of Deep Drawing with Draw Bead Die.

Bezier curves technique is used to design draw bead. The mathematical formulation of Bezier techniques published in[8], (2016) Zahraa AbdAlkareem MCS in Technical Engineering College, control point soft draw bead are:

\[ b_0 = (0,0,0), \quad b_1 = (-1.4, 0.8, 0), \quad b_2 = (0, -1.4, 0), \quad b_3 = (5, 0, 0) \]

Using MATLAB program is built to generate the curve of draw bead as shown in Figure 1.

![Figure 1. The central points of the draw bead curve with Bezier curve.](image)

A typical cylindrical cup drawing process was chosen for detailed analysis in deep drawing process with draw beads. The cup (63.5mm) outer diameter and (40mm) height is axisymmetric and the blank from which it is formed has a diameter (109mm), a thickness of (0.7mm) aluminum, brass and steel. This cup without flange, and completely drawn into the die. Figure (2) illustrated the design of deep drawing die and punch with draw bead. Figure (3) illustrated the manufacture die and punch with draw bead. The dimensions of punch and die used in experiments work is:

- the punch (61.75mm) diameter with corner radius \( d_p = 4 \text{mm} \).
- the die (63.5mm) inner diameter with the corner radius \( d_d = 4 \text{mm} \).

The experiment was carried out using a universal testing machine (UTM) of 300 kN capacity with required tooling was used for deep drawing process. The tooling for deep drawing was mounted...
on universal testing machine (UTM). In this work study the effect of draw bead on the production of cylindrical cup in deep drawing process with parameters three metal is taken (Al, Br, St), three lubricant (lithium grease, food machinery grease, wax), three punch velocity (3, 6, 9) mm/min and it's found the position of draw bead also has significant effect in determination of defect. Two distances (45, 39) mm center of draw bead to center of cup were adopted. The distance of 39 mm gives successful product, while 45 mm distance causes failure of product.

![Figure 2. geometry of the tools used.](image)

![Figure 3. The manufacture die and punch with draw bead.](image)

3. ANSYS analysis of deep drawing with draw bead.
The mathematical formulation of Bezier techniques have been applied and integrated with MATLAB program (v.II) to create the draw bead profile depending on initial control points. The deep drawing with draw bead model is created, due to axisymmetric in geometry and loading the 3-Dim model is analyzed [9]. Figures (4)& (5) illustrated the process.
4. Results and Discussion.

4.1 Effect of Draw Bead on Producing Cup without Defects

In order to investigate the effect of draw bead with design proposed in the current study on improvement of product, comparison was adopted between product without draw bead and product with draw bead. Figure (6) shows that the draw bead play an important role in prevent occurrence of wrinkling especially with aluminum rather than brass and steel at 9mm/min velocity of punch and using wax as a lubricant for aluminum. Wrinkling occurs because of compressive circumferential stress and insufficient blank holder pressure, in addition, the die may be not a center with respect to punch which permit metal to flow more easily on one side than on the other. Aluminum metal characterized with low ductility in comparison with brass and steel, so in deep drawing process it suffered from less draw ability.
The draw bead prevents wrinkling for aluminum because it makes the metal flow uniformly and slowly. The position of draw bead also has significant effect in determination of defect. Two distances (45,39)mm center of draw bead to center of cup were adopted. The distance of 39mm gives successful product, while 45mm distance causes failure of product. When draw bead far away from the end of die, this cause in counter of metal flow and distance of 39mm was optimum to draw the blank in the die. Figure (7) shows the samples of failure specimens because of unsuitable distance of draw bead, the female of draw bead is on the die and the male on the blank holder as usual used in previous studies.

4.2 Effect of Draw Dead on Deep Drawing Load.
FEM results related relationship between punch load and displacement for three metals at 6mm/min velocity are illustrated in Figures (8) & (9).

Figure 6. specimen in velocity 9mm/min, with & without draw bead.

Figure 7. cups of position 39mm.
Figure 8. (a,b,c) F.E relationship between punch load and displacement for three metal at 6mm/min velocity.
Figure 9. (a, b, c) relationship between punch load and displacement for three metals experimentally and F.E with draw bead at 6mm/min velocity.

Compare the three metals using the draw bead, figure (10), shows a comparison of the punch load against punch stroke for three materials (aluminum, brass and steel), using a velocity 3mm/min with draw bead. It is evident that the maximum drawing force of the steel is higher than the other two materials, because this material is work harden at faster rate than the other two materials, which requires higher forming pressure, and for brass is higher than aluminum due to the lower tensile strength of aluminum which requires less pressure to deform.
4.3 Effect of the Lubricant & Speed.

Good drawing practice aims to increase friction between the blank and the punch bottom and radius and minimize it at the blank and die lip surface. Thus lubricant with high slip properties must be applied to the die surface and blank surface face to die. In this work, to investigate the effect of lubricant on deep drawing process three types of lubricant are chosen (lithium, machinery food and wax). Using wax because the only one which succeeded aluminum with draw bead. Figure (11) it is deep drawing without draw bead clear from it is evident from the figure that the maximum drag force decreases when using low speed except lithium 3 mm/min for lubrication, and the reduction of maximum force is not affected by the lubrication is final, where the use of lithium grease and food machinery. So that compared with figure (12) FEM for three types, the average of error 15.0966%.

Figure 10. (a, b) effect of load on punch load for different material (aluminium, brass, steel), velocity 3 mm/min

A. using lithium grease, only AL wax

B. using food machinery grease, only wax for AL
Figure 11. Effect lubricant & speed on longitudinal strain without draw bead for Al.

Figure 12. (a,b,c) effect longitudinal strain on speed 3, 6, 9 mm/min with lithium lubricant FE and experimental for Br.

Figure 13 that`s with draw bead use wax for lubricant, be better compared to without draw bead behave somewhat disciplined. So that compare with figure (14) FE for all types, average error 9.895833%.

Figure 13. Effect lubricant & speed on longitudinal strain with draw bead for Al.
Figure 14. (a,b,c) effect longitudinal strain on speed 3,6,9mm/min with wax lubricant ansys and experimental for Al.

Figure 15 deep drawing without draw bead for brass, high speed shows better than the slow speed of the strain, but it changes for the strain speed 3mm/min using lithium and then the resultant strain, that did not change the bottom of the cup. Compare it with the (16) chart FE, average error 18.19444%.

Figure 15. Effect lubricant & speed on longitudinal strain without draw bead for br

Figure 16. (a,b,c) effect longitudinal strain on speed 3,6,9mm/min with lithium lubricant FE and experimental for br.

Figure 17 deep drawing with draw bead for brass, here shows the smooth strain and shows the effect of speed and lubrication well to compare with the without draw bead because of the first strain of the bead of drag and increase the tensile of the blank on the punch. Figure (18) the FE for brass with draw bead, the average error 14.08333%.
Figure 17. Effect lubricant & speed on longitudinal strain with draw bead for br.

Figure 18. (a,b,c) Effect longitudinal strain on speed 3,6,9 mm/min with lithium lubricant FE and experimental with draw bead for br.

Figures 19 and 20 deep drawing with and without draw bead to steel, in this figure shows the effect of the bead of the pulled of speed and lubricant as a uniform and ultimately the strain is constant and this is good compared to the without draw bead the pulled is considered random at first and then drained, use lithium and machinery food for lubricant, the ratio of error by comparison 17.1% with draw bead, 19.59259% without draw bead. That did not change the bottom of the cup for all cause, at the next zone (punch corner) thinning will occur because of stretching exerted by tensile stress and its clear that the effect of lubricant not large, afterward at the cup wall thickness tends to increase, and this is caused by the compressive stress applied to this region and approximately have the same values for all the cases. For all above figure can conclude that when using the draw bead its effect on the effective strain because the shape of bending-unbending is change so that the strain in every direction is change caused by the change in friction.
Figure 19. Effect lubricant & speed on longitudinal strain with draw bead for St.

Figure 20. (a,b,c) Effect longitudinal strain on speed 3,6,9mm/min with lithium lubricant FE and experimental with draw bead for steel.

Figure 21. The effect of lubricant and speed on hoop strain with draw bead for Al. The value of hoop strain is zero at cup bottom where no deformation occurs, afterward it becomes positive at the cup corner (expand in circumference) due to tension stress in this, then begins to decrease towards cup wall to have negative value (shrinkage in circumference) because of the compression applied in this direction and it continues to decrease to reach a maximum value of (0.31) at the cup rim, the percentage error 18.7029% shown in Figure (22).
Figure 22. (a,b,c) effect hoop strain on speed 3,6,9mm/min with wax lubricant FE and experimental with draw bead for Al.

Figure 23. the effect of lubricant and speed on hoop strain for brass withdrew bead, here there is no tangible strain change between the presence and absence of bead, the same as aluminum. percentage error 11.829% as shown in figure 24.

Figure 24. (a,b,c) effect hoop strain on speed 3,6,9mm/min with lithium lubricant, FE and experimental with draw bead for br.

Figure 25. the effect of lubricant and speed on hoop strain for steel withdrew bead, the worst one with 3mm/min, lithium lubricant, give value of (0.3) before rim zone, so that compared with FE in figure (26) and average error 8.8320%.
4.4 Effect Thickness Strain on Product

Figure 27 represents the relationship between the thickness strain that distributed on the product and the distance from cup center, for aluminum with draw bead. so compared with figure (28) FE, the average error 11.6401%. Observing that the thickness is constant under the punch base, and then increases on the cup wall until a maximum value obtained on the cup wall. The hoop stress (circumference) tend to cause thicken the blank in the end of the cup wall. The friction and stretch will occur over the punch nose the blank thinning near the punch base.
Figure 28. (a,b,c) effect thickness strain on speed 3,6,9mm/min with wax lubricant FE and experimental for Al.

Figure 29 nearly coincidence between the two positions relative to thickness to same speed and lubricant. The variation is about 0.17% in thinning and 0.1% in thickening, that for brass with draw bead and average error 9.3574% for FE in figure 30.

![Figure 29](image)

Figure 29. effect thickness strain with draw bead for br.

Figure 30. (a,b,c) effect thickness strain on speed 3,6,9mm/min with lithium lubricant, FE and experimental with draw bead for br

Figure 31 the variation between the maximum value of variation at (9mm/min) and the minimum value variation at (6mm/min) is about 8.6% in thinning and 14% in thickening, that for steel with draw dead, as shown in figure 32 percentage error % for FE.
Figure 31. effect lubricant & speed on thickness strain with draw bead for st.

Figure 32. (a,b,c) effect thickness strain on speed 3, 6, 9 mm/min with lithium lubricant, FE and experimental with draw bead for st.

Figure 33, 34 and 35 effect thickness strain for three metals in sequentially without draw bead, found high value 42% and low value 30% to aluminium 3 mm/min, the remaining metals behaved similarly to all speed and lubrication.

Figure 33. effect lubricant & speed on thickness strain without draw bead for al.
5. Conclusions:
1. The draw bead (Bezier curve's equation) play an important role in prevent occurrence of wrinkling especially with improved aluminum samples.
2. The effect of high strength when not use the draw bead from the presence of the bead for aluminum, it is noticed that the maximum drawing force will increase. This occurs because of the increase of strain hardening of material with drawing speed, which leads to an increase in drawing stress, and finally increasing drawing force, that due to lubricant grease.
3. Chose wax because the only one which succeeded aluminum with draw bead.
4. Draw bead use wax for lubricant be better compared to without draw bead behave somewhat disciplined. So that compare with experimental and FE for all types, so average error 9.895833%.
5. The ratio of error by comparison 17.1% with draw bead, 19.59259% without draw bead to lubricant &speed on longitudinal strain for steel.
6. The effect of lubricant and speed on hoop strain for steel with draw bead, the worst one with 3mm/min, lithium lubricant, give value of (0.3) before rim zone, and average error for FE and experimental 8.8320%.
7. The relationship between the thickness strain that distributed on the product and the distance from cup center, for aluminum with draw bead. the average error for fe and experimental 11.6401%.
8. Effect thickness strain for three metals in sequentially without draw bead, found high value 42% and low value 30% to aluminium in 3mm/min, the remaining metals behaved similarly to all speed and lubrication.

9. The best one aluminum with draw bead it is clearly seen at its best results where for all speed use wax to lubricant but in 3mm/min take that perfect.

10. The best thickness variation for brass of without draw bead, when compared that with it. Evident because of the change in restraining force found two step of bending-unbending shape. and for galvanized thickness that not tangible.

11. The symbol aluminum 9mm/min and use machinery food to lubricant, without draw bead, represents the failed in deep drawing cases.

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