Contents lists available at http://qu.edu.iq

Al-Qadisiyah Journal for Engineering Sciences

Journal homepage: http://qu.edu.iq/journaleng/index.php/JQES

Numerical and experimental analyzes of forming parameters of low carbon steel

Khalida Kadhim Mansor

Department of Production Engineering & Metallurgy, University of Technology, Baghdad, Iraq

ARTICLE INFO

Article history:
Received 2 October 2022
Received in revised form 20 Nov. 2022
Accepted 27 November 2022

Keywords:
Deep Drawing Process
coefficient of friction
Die shoulder radius
low carbon steel
forming load

ABSTRACT

Understanding sheet metal forming presses are important to reduce manufacturing costs. Thus, the best method of finding the optimum values of processing is by studying the effect of forming parameters on the behavior of formability, friction, and die radius. In this work, the deep drawing process of a low-carbon steel cup was studied and the significance of two important process parameters are investigated which are the friction coefficient and the radius of the die. The finite element method program, ANSYS, is used to study the effect of these parameters on forming load in the deep drawing process. The three levels of friction coefficient are considered which are 0.08, 0.00, and 0.15, and three die shoulder radius of 4, 6, and 8 mm. The results show that the predicted behavior of the punch load coincided well with both experimental and practical behaviors and the confidence is exceeding 94%. The wrinkling defect is happening when using a high die radius, Rd=8mm although the punch load is low due to the increase in the surface area on the edge of die.

1. Introduction

One of the most important manufacturing processes is the sheet metal forming which is considered is a cheap process when using in the mass production in industries application [1]. Deep drawing is used to manufacture a cylindrical cup with constant thickness distribution[2]. The initial shape of deep drawing blank is a flat circular blank which is set to form the cylindrical cup. Forming load was applied on blank by using punch and die to form the desired shape without folding the corners. a double action for punch force and blank holding force was applied at the same time on the blank to achieve the forming part. Deep Drawing can also be defined as the combined of compression and tensile deformation of a sheet to form a hollow body at the constant sheet thickness [3]. Below are details about the most importance parameters that effect of forming load in deep drawing process.

1.2 The effect of friction

The most important variable in drawing process is the friction. The forming force, blank holder type, and blank holder force are depended on the friction value. The hollow bodies that are produced as a result of applying deep drawing process on metal blanks using die, punch, and blank holder, have

* *Corresponding author.*
E-mail address: khalida.k.mansour @uotechnology.edu.iq *(Khalida Kadhim Mansor)*

https://doi.org/10.30772/qjes.v15i4.854

an impact the on selection of lubricant. Also, the friction type is a complex process in comparison to other processes due to the need f a low friction in sometimes, and also a high friction in other applications [4].importanttance parameters affectffect on friction is the selection of lubrication type as well as friction coefficient.

1.2.1 Lubrication effect

The galling (pressure welding) between the die-blank and punch blank metal is happened in drawing process due to the sliding contact under pressure [5]. Drawing force increases when an extreme galling which occurs and unequal load distribution causes a fracture in the work piece. One of the most factors to prevent the failure such as wrinkling or tearing is the selection of the suitable lubricant during the deep drawing process as well as the ease of use and removal [6].

1.2.2 Friction coefficient

When using high value of friction coefficient, the wrinkling defect can be eliminated. However, in this case, the load distribution will be unequal, and consequently, this causes cracks and fracture in the material as shown in fig. 1,.The friction coefficient redound of (6.33%) of the total variance in the height of the drawn cup. The coefficient of friction increases with respect to the increase in the drawing cup height[7]. The risk of its wrinkling is occurred due to the tangential compression stress. This risk is likely occurred if there is a big difference between the initial blank diameter and the final diameter of forming cup and the sheet thickness is small [8].Yang, used the finite element method (FEM) to simulate the deep drawing process, and studied the strain distribution under different friction coefficients, and then applied the results in an experimental work and conducted a comparison between them [9].

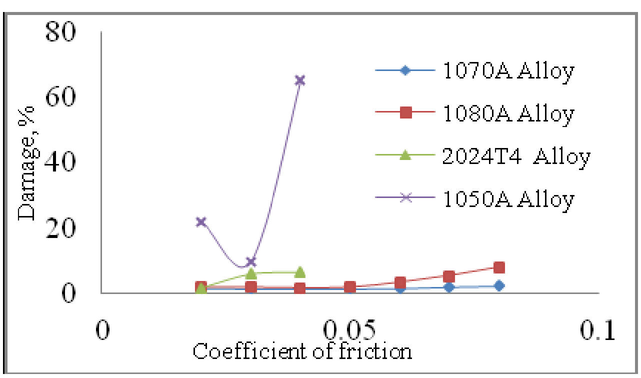


Figure 1. Influence of the friction coefficient on the material's damage[8]

Liu Qiqian et. al. (2012) analyzed the process of microdot formation with a pillow using FEM that used to study the effect of the forming size and simulate the micro-forming process in multiple-points. The research aimed to study the effect of friction coefficient between materials on the surface finish and distribution of thickness of the final product from the center to the edge in the deformed plates[10].

2. Objective

The aim of the work is to show the:

1. Study of the effect of friction coefficient on punch load as well as the wrinkling defect.
2. The Effect of die radius on forming behavior and formability.

3. Theoretical consideration

The important variables that affect the quality of the product are punching force (Fdr), the radiuses of die and punch (Rd, Rp), blank holding force (BHF), blank thickness (t), and the ratio of the draw which includes the ratio of the blank diameter to the punch diameter (D/d). In addition, material properties influence the product quality and cost in sheet metal forming process. Fig. 2 shows the deep drawing process geometric variables.

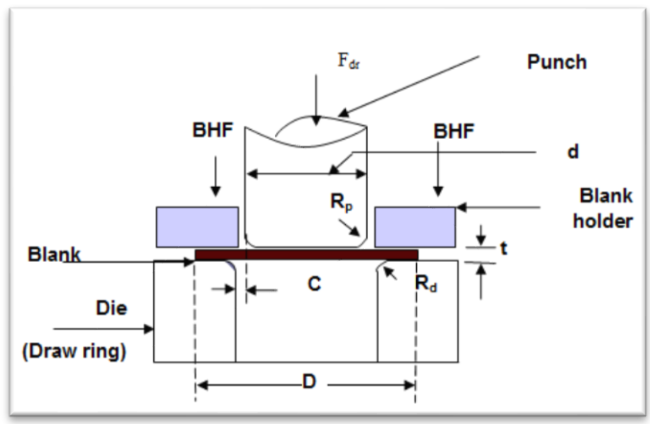


Figure 2. Schematic the deep drawing process

3.1 The drawing force

The work required to draw the blank into a cup is supplied by the punch force. The force exerted by the punch depending on the process parameter. The work required is a combination of pure deformation work and frictional work. The deformation work also depends on the fact that the forming mechanism is pure stretch forming, pure drawing or combination of both. A great many parameters are involved in determination of deformation work and consequently the punch force. Certain simplifying assumptions have to be made in order to determine an expression for maximum punch force [11].

This force can be estimated by following equation:

$$Fdr = \pi * d * t * \sigma u * (\beta - G) \quad (1)$$

Where:
Fdr= drawing force
σu = ultimate tensile stress
G = constant (0.6 – 0.7) to cover bending and friction
It was observed that by varying the metal volume and metal resistance, the punch force will be increased and reaches to the maximum value, and after that top point, it been gradually decreases to zero. The maximum value of drawing force occurred when the punch depth is equal to (Rp+Rd), or at value around (0.333) of the punch stroke length [12].

3.2 The influence of friction

When the friction between blank and punch increases, it can be seen that the material flows from underneath the punch bottom over the punch nose. The high friction coefficient will prevent the flow of material over the punch nose, which in turn will prevent excessive stretching of the sheet metal at the bottom of the punch, and consequently increases the limit drawing ratio (LDR). The high friction coefficient between die and sheet will decrease the LDR. Existing the friction over the die corner radius and in the flange, causes a difficulty in drawing of the sheet metal. It will increase the required punch force. This situation will cause excessive stretching and a fracture in the unsupported regions. Fig. 3 shows the coefficient of friction increases when the limiting drawing ratio (LDR) was decreases [13].

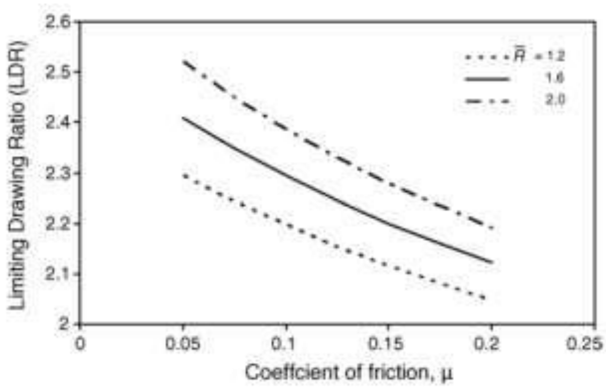


Figure 3. Relation between friction coefficient and LDR [13]

The friction resistance stresses (τf) for flat surface is a result of multiplying of the friction coefficient (μ), and the blank holder pressure (P), as illustrated by the following equation:

$\tau f = \mu * p$ …(2)

And, for the inclined surface has an angle (α):

$\tau f = \mu * p * \cos(\alpha)$ ...(3)

3.3 The influence of die profile radius:

Die radius (Rd) depends on the workpiece size and thickness, and large radius of die is required to use in order to increase the limit drawing ratio and also to reduce the drawing load. However, there is a decrease in the contact area between the empty holders at using of large die radius. Additionally, there is an increase in the probability of occurrence of the wrinkles [14].

4. Numerical simulation

FEM was used to analyze the forming process under the specified working conditions that entered by the users. The users are changing and repeating the conditions and conducting the analysis until they find the suitable conditions that reduce the efforts of the users in numerical simulation, which used to:

- Predicting the material flow during the particular process (on the draw beads in deep drawing).
- Predicting the punch force, blank holder force and the stresses that are necessary to execute the forming process.
- Prevent the failure which could be caused by the defect in die-punch design.

In this work the commercial finite element package (ANSYS 14) is used to simulate the process of draw bead in deep drawing process for cup forming. The numerical results have compared with the experimental results. The punch, die and the blank holder represented by (Target 169), which defined by three nodes, and each node has two degrees of freedom. The blank material represented by (Visco 106), which defined by four nodes, and each node has up to three degrees of freedom.

The contact interface between die and the deformed material is represented by (Contact 171), which has two degrees of freedom at each node. The loading was conducted in the form of a prescribed displacement. The isotropic hardening plasticity model have been used. As the driving force to obtain plastic response, the Von Mises stress has been applied to compute by the most commercial FEM package as illustrated in fig .4.

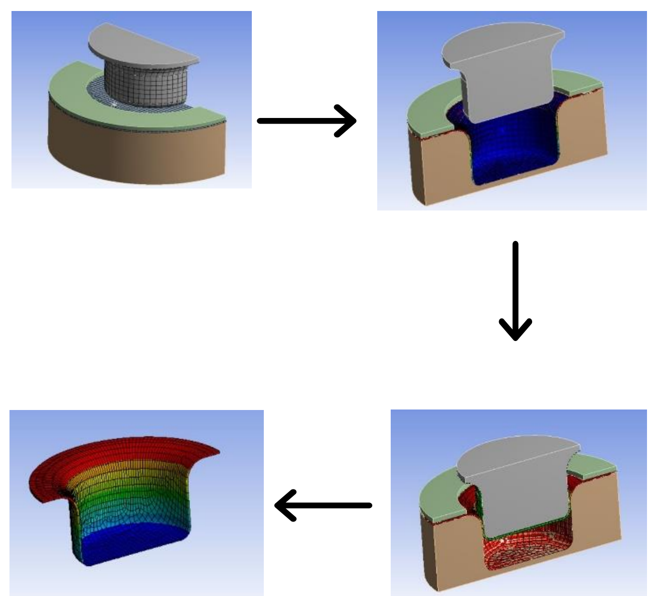


Figure 4. Simulation of present work using ANSYS (14) program

The result of deep drawing analysis was illustrated in table 1. with different coefficient of friction and their effect on punch load variations when the die radius is 4. And after that, a numerical simulation was performed to investigate the effect of die radius on deep drawing process. Different simulations with two die radius; 6 & 8, and at different coefficient of friction; 0.08, 0.1, and 0.15 were performed.

Table 1. illustrated the result using finite element at different coefficient of friction (Rd=4mm)

μ=0.15 without lubrication		μ=0.1 using wax		μ =0.08 with graphite and grease	
Punch stroke	Punch load	Punch stroke	Punch load	Punch stroke	Punch load
0	0	0	0	0	0
0.9854	1.235	1.0752	1.165	1.0102	0.9025
3.0124	5.364	2.2542	5.231	2.9956	3.365
5.9854	10.089	6.3674	9.9806	6.1202	7.5326
9.1235	20.147	9.3275	18.0123	9.2235	15.6541
11.9852	22.457	13.533	20.4561	13.0125	18.9541

14.9582	26.4971	15.5451	23.2564	15.212	23.4587
16.3652	28.9522	18.1106	26.4589	18.125	25.6871
18.5682	31.512	20.1204	30.2101	19.2669	28.3654
19.6985	32.3425	22.9841	31.123	20.2365	29.5841
22.8562	32.0143	24.721	30.952	23.256	25.3641
24.2658	30.478	26.0985	29.7841	25.2365	21.0124
25.9856	27.1438	26.2854	25.142	26.321	19.2541
28.0125	18.42	28.1235	17.5421	28.0112	15.2364
28.9985	15.0954	29.1024	14.4536	29.1145	11.131
31.3254	12.3246	31.5012	11.4581	31.3956	9.5471

5. Experimental work

After applied the finite element analysis with appropriate forming condition and used this result in experimental work. The experimental work conducted using INSTRON universal testing machine which has a force capacity 180 KN and speed of the testing was kept constant at 10 mm/min. The forming blank has 80 mm a diameter, 0.5 mm thickness, and made from low carbon steel (1006–AISI) of the following mechanical composition is listed in table 2. A typical cylindrical cup drawing process was chosen for detailed analysis in deep drawing process with draw beads that presented in fig. 5. The cup (40 mm) outer diameter with die profile radius (Rd=4, 6 and 8) and punch diameter (38.8mm) with corner radius (Rp=2mm) was used to completely drawn the die that shown in fig 6.

Table 2. low carbon steel mechanical properties (1006–AISI)

Property	Value
Young modulus (Gpa)	200
Position ratio	0.3
yield stress (MPa)	125
tangent Modulus (GPa)	0.52

The experimental result of deep drawing process was illustrated in table 3. with different coefficient of friction and their effects on the punch load variations when using die radius (Rd=4). Following, the experimental work was conducted with die radius (Rd=6) and die radius (Rd=8) and the coefficient of friction varies from a low of 0.05 to 0.2.

Figure 5. Experimental setting of deep drawing process

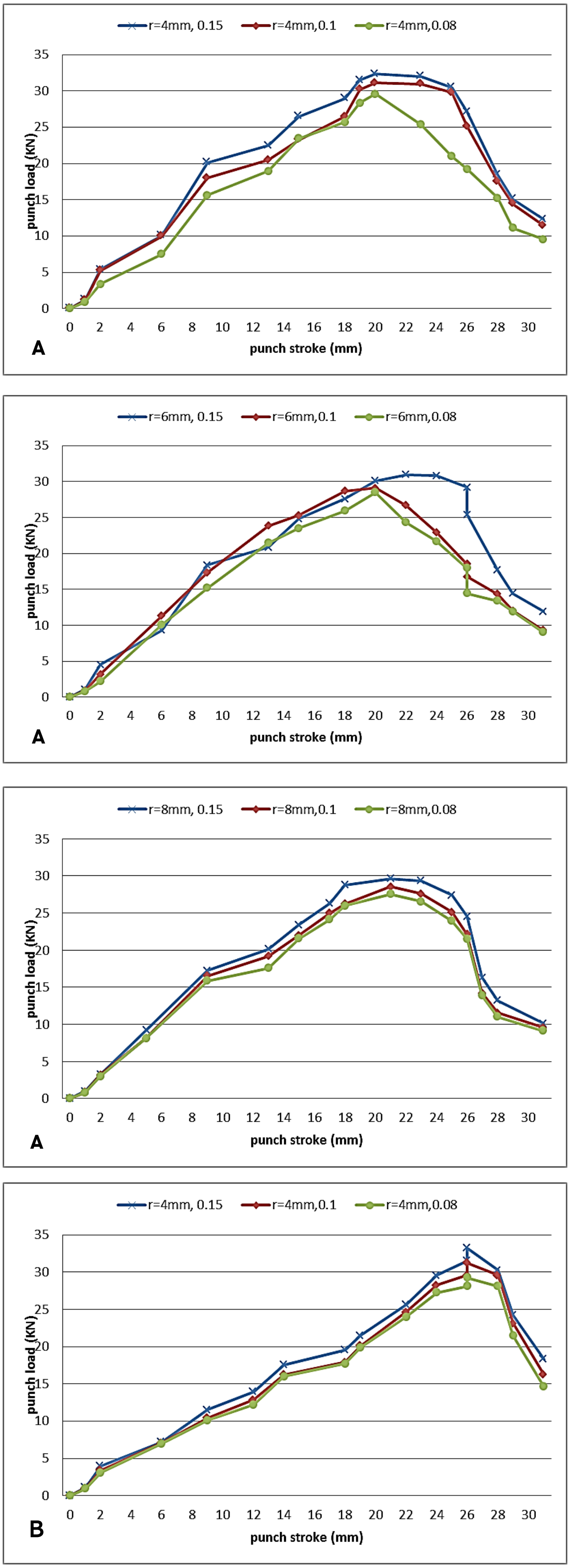
Figure 6. Samples of completely drawn cup

Table 3. illustrated the result of experimental work at the different coefficient of friction (Rd=4mm)

μ=0.15 without lubrication		μ=0.1 using wax		μ =0.08 with graphite and grease	
Punch stroke	Punch load	Punch stroke	Punch load	Punch stroke	Punch load
0	0	0	0	0	0
1.121	1.14	0.998	1.012	1.002	0.958
2.312	3.985	2.341	3.457	2.262	3.12
6.21	7.214	6.187	7.101	6.214	7.011
9.241	11.561	9.365	10.452	9.353	10.124
13.501	13.985	12.785	12.875	12.675	12.231
15.212	17.567	15.321	16.245	14.985	15.998
18.21	19.587	18.01	17.895	18.142	17.745
20.31	21.542	19.998	20.154	19.874	19.895
22.695	25.654	22.11	24.652	22.562	23.997
24.575	29.584	24.352	28.245	24.152	27.254
26.213	31.524	26.114	29.587	26.241	28.114
26.562	33.254	26.568	31.251	26.415	29.245
28.141	30.241	28.21	29.584	28.325	28.114
29.256	24.251	29.14	23.154	29.354	21.457
31.378	18.354	31.375	16.254	31.241	14.654

6. Results and discussions

Variation of the friction coefficient, the die radius in nine different cylinder shapes (3x3) is considered to study their effect on the forming process behavior, in particular the punch load. Fig. 7 illustrated the relationship between the punch load and the punch stroke in simulation and experimental works. While, fig. 8 presents the confidence between the punch load in numerical and experimentally at different values of coefficient of friction. It has seen from the figure for μ=0.15 (without lubrication), the required forming load is 33.254 KN. While for experiment under coefficient of friction 0.08, radius equal to 6 mm, and the lubricant is grease, the forming force is down to 28.998 KN and there is no difference in the simulation and experimental results under the same conditions of coefficients of friction. wrinkling defect occurs when the applied punch load is at lower level and coefficients of friction 0.08 accompanying with using graphite and grease as a lubricant.



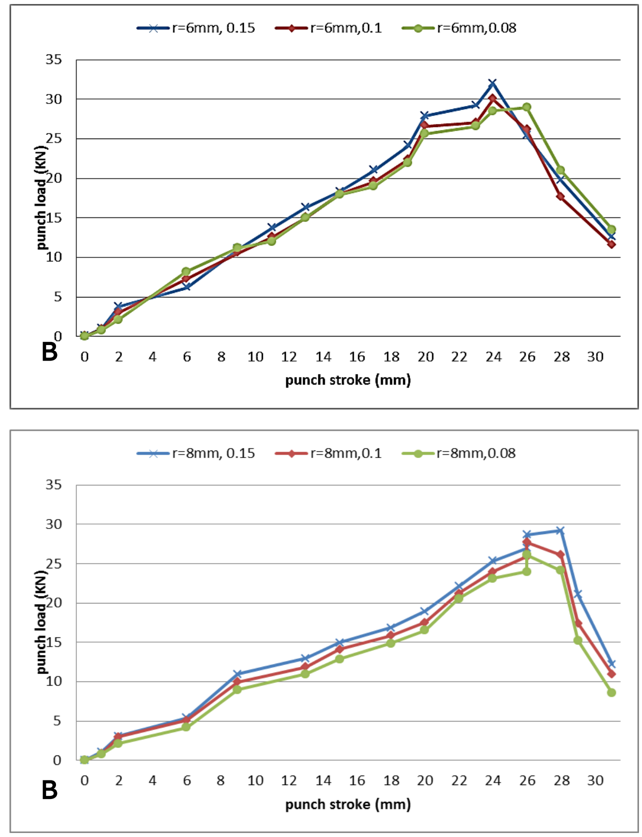


Figure 7. The relation between punch stroke and punch load, (A) Simulation, (B) Experimental

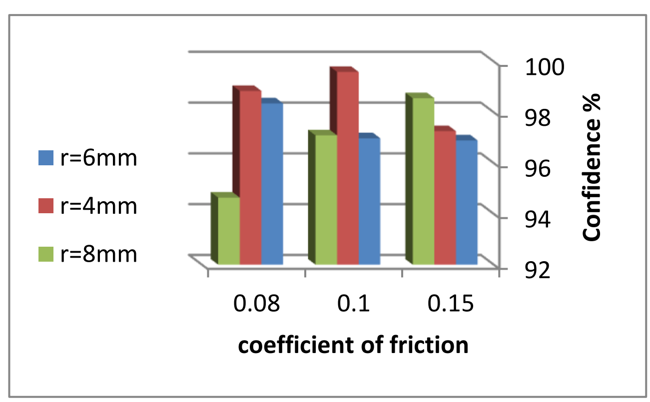


Figure 8. Confidence between FEM and EXP. with different parameters.

7. Conclusions

1. Finite element method was used to simulate the forming process of a cylindrical shape and the result has been compared to experimental work with different values of parameters (coefficient of friction and die radius).
2. From the results shown in figures (7), the predicted behavior of forming process was clearly indicated that the punch load with coincided well with

both analytical and experimental behaviors and the overall deviation are not exceeding 6%.

3. The effect of two die geometry parameters: die radius and coefficient of friction, on the load forming distribution were studied by simulation and experimental work. The results showed when the coefficient of friction increases and die radius decreases, the forming force will be increased.
4. From the results, they show that using high die radius (Rd=8) with applying low force punch, is a main reason for occurring of wrinkling defect.

REFERENCES

[1] Tahir Altinbalik, Aysun Tonka, Numerical and experimintal study of sheet thickness variation in deep drawing processes, International Journal of Modern Manufacturing Technologies ISSN 2067–3604, Vol. IV, No. 2 / 2012

[2] A.D.Younis, The effect of drawing ratio in deep drawing process on thickness distribution along the cup, Al-Rafidain Engineering Vol.18 No.4 August 2010

[3] D.Swapna, Ch.Srinivasa Rao, S.Radhika, B.RaviRaja, DEEP DRAWING PROCESS: A BRIEF OVERVIEW, NCAMMS 2015

[4] Ter verkrijging van: “Modelling of contact and friction in deep drawing Processes”; Printed by FEBO druk B.V., Enschede; Printed by FEBO druk B.V., Enschede

[5] Nayan Kaneriya, Darshan Shah, Rishit Rana, Vaishal Shah, Parth Thakkar, Effect of Different Parameters on Deep Drawing Process for Minimum Stress and Defects by Experimental and Simulation Study: A Review, International Journal of Advance Engineering and Research Development Volume 3, Issue 10, October -2016

[6] A. R. JOSHI, K. D. KOTHARI, Dr. R. L. JHALA, Effects Of Different Parameters On Deep Drawing Process: Review, International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 3, March – 2013

[7] A. Chennakesava Reddy “Parametric Significance of Warm Drawing Process for 2024T4 Aluminum Alloy through FEA”, International Journal of Science and Research, vol. 4, no. 4, pp. 2345-2351, 2015.

[8] Devendar.G, A. Chennakesava Reddy, Study on Deep Drawing Process Parameters - A Review, International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016 ISSN 2229-5518

[9] T.S. Yang “Investigation of the Strain Distribution with Lubrication During the Deep Drawing Process”, Tribology International, vol. 43, pp 1104–1112, 2010.

[10] Liu Qiqian, Lu Cheng, Fu Wenzhi, Tieu Kiet, Li Mingzhe, Gong Xuepeng “Optimization of Cushion Conditions in Micro Multi-Point Sheet Forming”

[11] Vukota Boljanovic "Sheet Metal Forming Processes and Die Design" ISBN 0-83 1 1-3 182-9 (2004).

[12] Kakandikar G.M. "Optimization of forming load and variables in deep drawing process for automotive cup using Genetic Algorithm " Prentice Hall of India Private Limited, New Delhi, pp 1-4, (2008)

[13] J. A. Schey, “Introduction To Manufacturing Process”, third edition, Mc Graw-Hill series in mechanical engineering an material science, ISBN 0-07- 0311, (2000).

[14] D. E. Ostergaard “Advanced Die making”, McGraw-Hill Book Company,(1967).

[15] Jalil Jabbar Shukur, Effect of Blank Holder Types on Drawing of Mild Steel Round Cup with Flange, University of Technology,2013