International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 08 | Aug 2018 www.irjet.net p-ISSN: 2395-0072

# Numerical Investigation of Two-Stage Shallow and Reverse Redrawing in One Direction without Blank Holder

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**Abstract -** *Deep drawing is one of the most widely used sheet metal forming operations. As the highest limit drawing ratio reached by a single-stage process is generally about two, the reverse re-drawing operation is usually adopted to achieve larger drawing ratios. In addition, the use of blank holder offers an extra cost and an additional force to the drawing system. Therefore, in the current paper, an FE model has been performed for simulating wrinkling, modeling stresses and strains and for predicting loads required for reverse re-drawing of sheet metal without using a blank holder. A carbon steel (AISI 1008) blank of 80 mm diameter and 0.5 mm thickness has been used. The speed of drawing has been set to be 200 mm/min for simulation. The setup of the drawing process has been submitted for producing cylindrical cups within two stages: direct or shallow drawing for the first stage and reverse re-drawing for the second one. DEFORM v10.2 software package has been utilized to accomplish the FE simulation. The results of the FE analysis show that the folding angle for the second stage is larger than that for the first one as a consequence of forcing the pre-deformed material to flow in the reverse direction resulting in more wrinkled regions during reverse re-drawing. Larger effective strains generated in the second stage as the drawing ratio becomes higher requiring more stretching to perform drawing. The maximum load predicted for the first and second stage is 24.244 KN and 26.933 KN respectively. However, an average of fluctuating loads within the second stage can be taken to make the maximum load value closer to that of the first stage.*

***Key Words***: Finite element (FE), shallow drawing, reverse re-drawing, folding angle, etc …

## 1. INTRODUCTION

Sheet metal forming is one of the most important production methods used in different industries such as producing industrial parts, office and home appliances, automobile body, airplane parts, etc. [1]. Deep drawing process is one of the most widely used process in metal working processes in general and in sheet forming in particular [2]. Deep drawing process has been used broadly in different industries. Considering the effect of input process parameters on the quality of deep-drawn products, several works can be accomplished regarding different aspects of this process [3]. It is performed to produce a very large variety of different geometrical shapes and sizes, like simple bend to double curvatures even with deep recesses and very complex shapes. Typical examples are automobile bodies and aircraft panels of good strength and light weight i.e. high strength-to-weight ratio and corrosion resistible products. Also it is used in producing appliance bodies and beverage cans [2]. In such process, the required parts are usually obtained in a single-stage, but in some conditions multi-stage process is required due to geometrical complexity or formability problems. Nevertheless, the minimum number of forming stages necessary to obtain the desired part without failure depends on many process parameters, being its determination, as well the shape of the tools for each stage, an enormous challenge. Since the maximum drawing ratio obtained with a single-stage operation is usually about two, the redrawing process is typically adopted when large drawing ratios are necessary [4]. In general, the redrawing process is classified in two categories: direct and reverse. The first drawing operation is the same in both types, whereas the difference occurs at the redrawing stage, as shown schematically in Fig. (1).

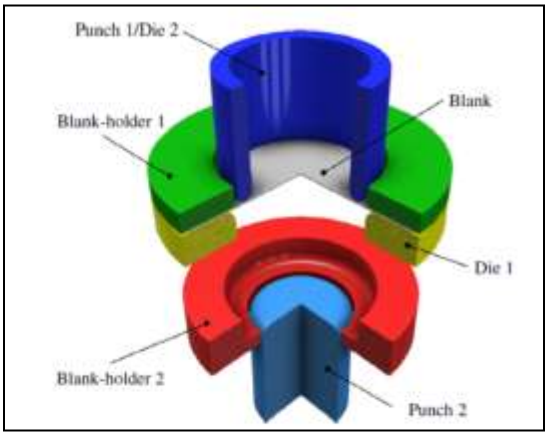


**Fig -1**: The reverse deep drawing of a cylindrical cup [4].

## 2. LITERATURE SURVEY

A group of studies related to reverse drawing has been conducted by many researchers in order to improve the formability of the sheet metal.

**S. Thuillier et al (2002)** [5] have dealt with the experimental and numerical reverse re-drawing of cylindrical cups. Experimental and simulated results lie within a range of 20%. The agreement is good in the first stage but problems are encountered for the second one: wrinkle formation overestimation of the punch force. Concerning the thickness predictions, they are closer to experiments.

**Z. Keran et al (2006)** [6] have made analyses of deep drawing Cr-Ni stainless steel process. The research is related to forces that appear in machine tool during the process. The researchers have concluded that reduction in number of draws is solved by reversed drawing. For the observed Cr-Ni stainless steel minimal reduction coefficient cannot go under 0.55 because the cracking occurs in the second draw. As well, punch force in the second draw is smaller, but by reduction coefficient changing, it also follows its own regression tendency curve.

**S.D. Zhao et al (2007)** [7] have developed a novel device of hydro-mechanical reverse deep drawing with axial pushing effect for cylindrical cups. Then finite element simulations and optimization are conducted and experiments are performed. A cup with a draw ratio of 2.95 is obtained. The study proves that the axial pushing force can improve the deformation extent of blanks considerably, and is one of the key factors for reverse deep drawing. The experimental results were in good agreement with the numerical simulation results. **R. Bortolussi et al (2009)** [8] done the simulation of deep drawing process and reverse re-drawing of cylindrical cups used in automotive parts industries. The results of this work allow to conclude that in the first step there are no significant differences among simulation and experiments in thickness minimum value and variation while in the second step thickness distribution had a different distribution in the cup wall but minimum values are the same at directions 0o and 45o and it also shows that mathematical model is accurate to simulate this process.

**Raman Goud. R et al (2014)** [9] have estimated the drawability of extra deep drawing (EDD) steel in two-stage forward redrawing process. The results show that EDD material blanks with various diameters and temperatures were drawn successfully. That is, direct redrawing has been successfully attempted. The fractures which have occurred are due to increase in blank holding pressure, exceeding the limiting draw ratio. Hence by redrawing process high draw ratios can be achieved in less number of steps and deeper cups can be obtained.

**K. M. Younis et al (2016)** [10] have presented an analysis of the multi-stage deep drawing process considering the three deformation stages namely reverse drawing and reverse redrawing respectively. This work aim to study the mechanism of deformation during the redrawing process where the second and the third stages were done in reverse redrawing and to study the effect of this mechanism on produced cup wall thickness, strain distribution across the wall of the drawn part. From this work it can be concluded that when considering multi-stage drawing, the task is even more difficult because the strain and thickness distribution resulting from the first stage will influence the subsequent results. In addition, more thinning appears in region under the punch profile radius due to excessive stretch in this region in the first stage. At last, increase in thinning in the wall cup will appear in the second and third stages because this region which suffers from more stretch in first stage will be wall cup in the next stages. In order to increase the maximum drawing ratio higher than this obtained in single-stage drawing, the reverse process has been adopted. In addition, the use of blank holder offers an extra cost to the drawing system and necessitates an additional force required to overcome the friction generated between the sheet metal and the blank holder. Therefore, in the current paper, an FE simulation campaign for modeling of wrinkling, stresses, strains and loads within reverse- deep drawing of a cylindrical cup without using a blank holder has been performed.

## 3. FINITE ELEMENT SIMULATION

Finite element analysis (FEA) is a simulation technique which computes the behavior of equipments, products and structures for different loading conditions. DFORM v 10.2 software was used to simulate the deep drawing operation. DEFORM is a finite element method based simulation system intended to analyze different forming operations. It minimizes the need for redesign of tooling and processes, improve tool and die design to reduce production and material costs, shorten lead time in bringing a new product to market. A 3D finite element model was imported and suitable material was assigned to the model. Various parameters were applied as in the numerical simulation to get verification of the results. The various stages of this simulation work are summarized sequentially in the following steps:

i. Preprocessing: defining the problem; the major steps in preprocessing are given below:
   a. Import geometry of top die/bottom die/ work piece/die holders (Solid Modeling),
   b. Mesh workpiece volumes as required,
   c. Define material/geometric properties.
ii. Solution: assigning loads/speed, constraints and solving:
   a. Apply the speed/loads (pressure),
   b. Position Objects (translational and rotational); primary die stroke; simulation control; generate data base,
   c. Switch to simulate; finally solve the problem.
iii. Post processing: further processing and viewing of the results, state variables and tools.

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### 3.1 Modeling of Parts

All parts including punches, dies and blank have been modeled as solids by using AutoCAD 2016 software package and then imported by DEFORM as STL files. Fig. (2) illustrates the modeled parts and their dimensional details. It is worth to mention that the blank has dimensions of 80 mm diameter and 0.5 mm thickness.

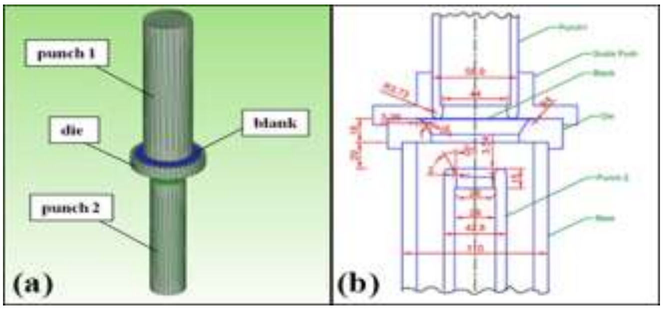


**Fig -2**: Parts assembly of deep drawing; (a) 3D view, (b) dimensional details.

### 3.2 Elements and Meshing

The type of element to be used in the analysis influences the exactness and accuracy of the results to a great extent. Literature review and examination of peer researchers' works show that tetrahedron 3-D elements have been conveniently used in the numerical analysis of anisotropic forming process. This element is capable of representing the large deflection effect with plastic capabilities. The main reason to use this type of element shape is the automatic re-meshing that is started in DFORM 3D for the highly destroyed element shape when simulation is running. Element size plays an important role throughout a simulation. Element sizes influence both the accuracy of the results and computation time. The blank should be meshed finer enough in order to get acceptable results. However, the increase in number of elements results in a drastic increase in computational time. In the presented study in order to achieve good results, numbers of element for the blank model is 69812. The process of meshing the sheet is shown in Fig. (3).

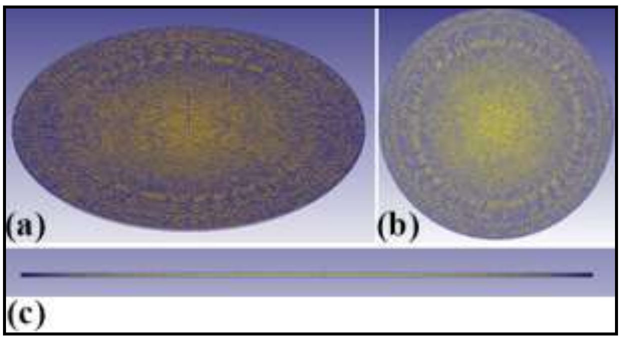


**Fig -3**: Meshing of the sheet metal; (a) 3D view, (b) Top view, and (c) side view.

### 3.2 Blank Material

The material of the blank sheet is low carbon steel AISI 1008 grade. It was selected as a plastic type material model in the presented DFORM-3D simulation. Punches and die are assumed as rigid, so there is no need to define material. The chemical composition and the mechanical properties of AISI 1008 material are listed in Table 1 and Table 2 respectively.

**Table -1:** Chemical composition of AISI 1008.

| C% | Si% | Mn% | S% | Cr% | Ni% | Mo% | Cu% | Ti% |
|---|---|---|---|---|---|---|---|---|
| * $10^{-2}$ | | | | | | | | |
| 6 | 1.5 | 36 | 3.3 | 3 | 5.9 | 2.9 | 5 | 0.8 |

**Table -2:** Mechanical properties of AISI 1008.

| Item No. | Mechanical Property | Value | Item No. | Mechanical Property | Value |
|---|---|---|---|---|---|
| 1 | Young's Modulus | 200 GPa | 4 | Ultimate Tensile Strength | 380 MPa |
| 2 | Yield Stress | 234 MPa | 5 | Strain Hardening Exponent | 0.214 |
| 3 | Poisson's Ratio | 0.3 | 6 | Friction Coefficient | 0.08 |

### 3.4 Boundary Conditions and Loading

As an important aspect of FE analysis, applying boundary conditions, load/speed consists of defining which parts from geometrical model moves (i.e. defining degree of freedom). Pairs of contact surfaces adopted in the present study are top blank - bottom punch 1, bottom blank - top die, bottom blank - top punch 2. In the current work the velocity of the blank sheet has been set 200 mm/min (3.333 mm/s) in Z-direction. Displacement load of the portion of the blank which is initially not in contact with the die is given in Z-direction. Movement of the blank which is on the die is unrestricted in both x and y-directions in order to permit the sheet metal to slide through the die cavity. The punches and die in FE simulation are considered rigid because they have extreme stiffness when compared to the material of the sheet metal.

### 3.5 Solution and Visualization of Cups

A proper modeling of geometry, meshing and correct applying of boundary conditions and loads have been performed. The punch velocity is applied and problem is executed for material as AISI 1008 grade. After all settings are complete, the simulation has been run. The solution has been carried out with displacement increments, with max number of steps set as 10000 and a minimum as 1 that represents the step increment in order to accomplish the total punch stroke which is set to be 75 mm for completing the whole drawing process. The resulting drawn cups for the first and second stages simulated by DEFORM software are shown in Figs. (4) and (5) respectively. It is important to mention that the dimensions of the shallow cup are 60 mm diameter and 12 mm depth while 44 mm diameter and 25 mm depth for the reverse drawn cup. FEM results demonstrate that there are no any cracks or tearing in all simulated cups.

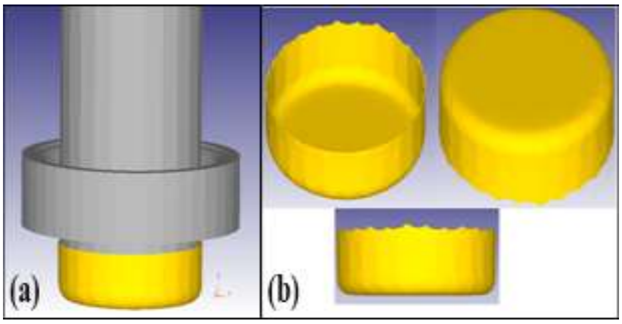


**Fig -4**: FE simulation of shallow-drawn cup (1st stage); (a) formed cup, and (b) different views.

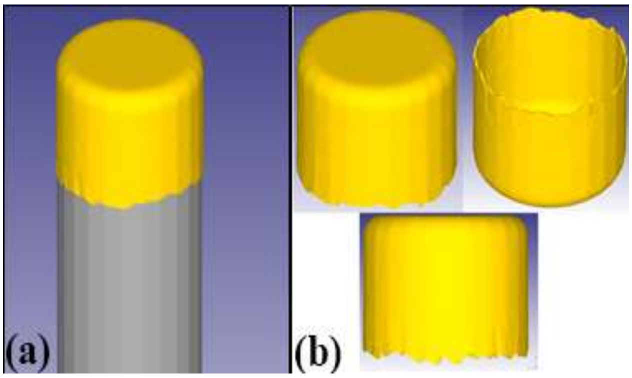


**Fig -5**: FE simulation of reversely deep-drawn cup (2nd stage); (a) formed cup, and (b) different views.

## 4. RESULTS AND DISCUSSION

### 4.1 Modeling of Wrinkling

The results of the FE analysis reached by DEFORM software demonstrate that there are no any cracks or tears observed in the walls of the simulated cups for both shallow and reversely deep-drawn cups. However, wrinkling has been noticed in the modeled cups as a result of the absence of the blank holder. Figure (6) shows the wrinkling that occurs in the drawn cups in terms of folding angle. Folding angle is a parameter through which the growth of wrinkling is to be evaluated. Higher folding angle means that more wrinkling to be induced. Folding angle varies up to 214° for the first stage which indicates that the drawing of sheet is more about 214° especially at the region of punch corner radius of the simulated cup while the value of such angle is equal to 354° for the second stage which is larger than the first one as a consequence of forcing the material to flow in the reverse direction resulting in more deformed and hence wider wrinkled region as shown in Fig. (6).

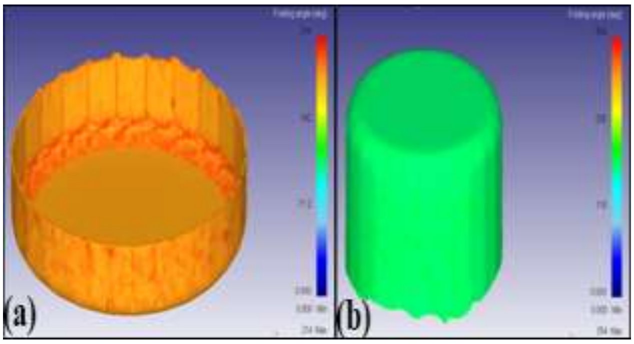


**Fig -6**: Wrinkling simulation of folding angle for (a) shallow-drawn cup (1st stage), and (b) reversely deep-drawn cup (2nd stage).

### 4.2 Simulation of Stresses and Strains

Second simulation has been tested for modeling Von Mises (effective) stresses and strains induced for both stages using DEFORM software as illustrated in Figs. (7) and (8).

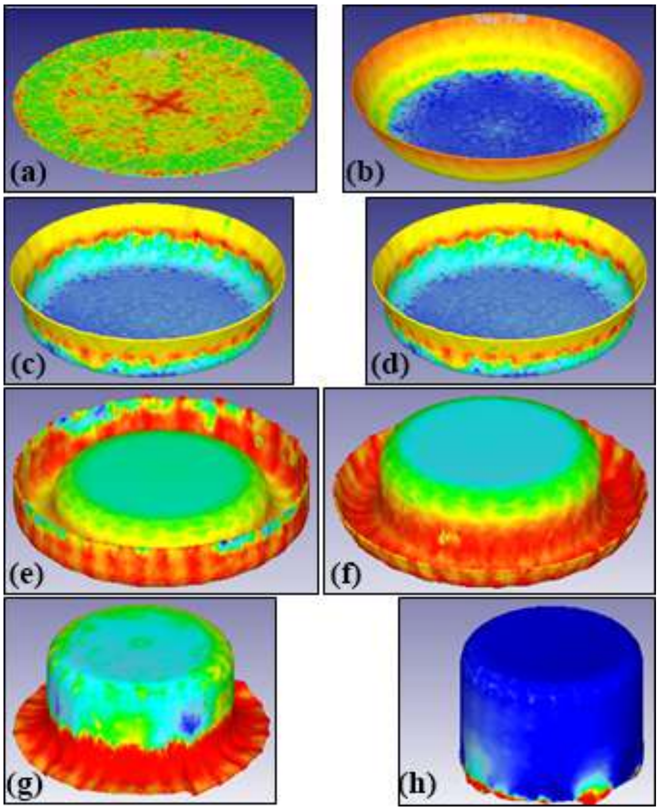


**Fig -7**: Effective stress distribution for: (a)-(d) shallow-drawn cup (1st stage), (e)-(h) reversely deep-drawn cup (2nd stage).

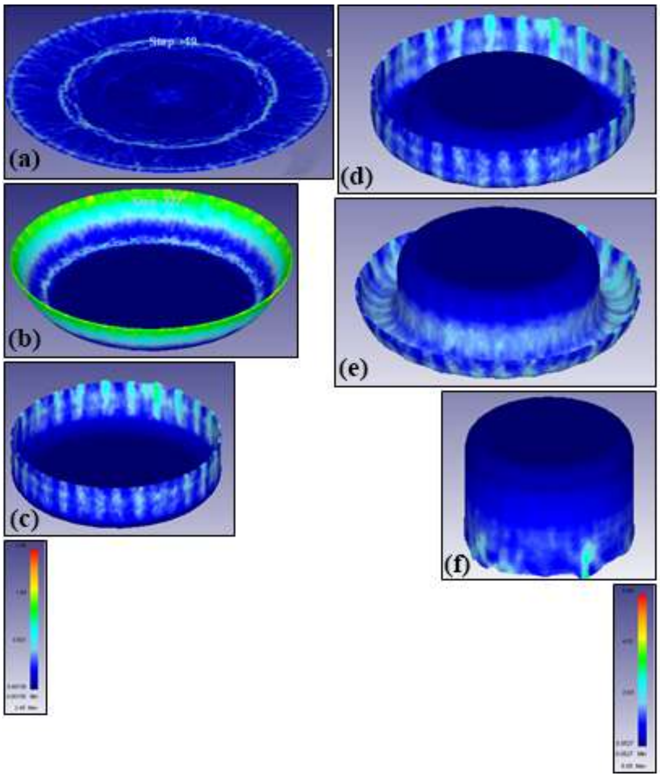


**Fig -8**: Effective strain distribution for: (a)-(c) shallow-drawn cup (1st stage), and (d)-(f) reversely deep-drawn cup (2nd stage).

Fig. (7) shows the total stresses distributed in the drawn cup. It is worth to mention that the dark blue color represents the lowest value while the red represents the highest value of stress. In general, small stresses have been generated in the bottom of the shallow-drawn cup except the initial steps that represent the onset of punch-sheet contact in order to force the blank to flow. Greater stresses (green and light blue color) have been observed on the bottom of the reversely drawn cup as a result of altering the drawing direction which accumulates the stresses in this zone. The forming of the cups along with the resulting strains are also presented in Fig. (8). It can be noticed that the strains are generally distributed on the walls (and near to walls) of the drawn cups for both stages as the flow direction of sheet aligns the cup wall. In general, no deformation in the bottom of the simulated cups because this zone is supported by the forming punches and makes a direct contact with them. In addition, effective strains that have been generated in the second stage are larger than those induced in the first stage as the drawing ratio becomes higher requiring more stretching to perform drawing. and could not be completed due to the unreasonable density of elements which makes the processing incomplete. Another suggestion for lessening the effect of this problem is to take the average of fluctuating load values in the range between the points (a) and (b) as indicated in Fig. (9-b) to make the maximum load value closer to that of the first stage.

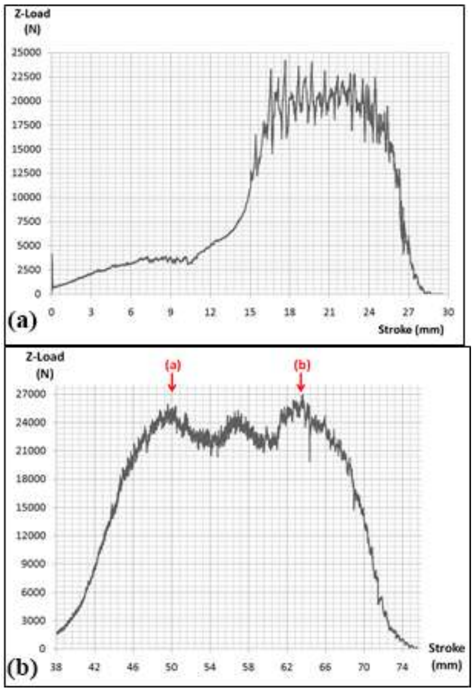


**Fig -9**: Load-displacement data by FE method for (a) 1st stage, (b) 2nd stage.

## 5. CONCLUSION

This work deals with investigating the reverse re-drawing of a cylindrical cup from a blank of 80 mm diameter and 0.5 mm thickness without using a blank holder. The FE investigation that has been performed allows to conclude the following remarks:

1. Folding angle varies up to 214° for the first stage which indicates that the drawing of sheet is more about 214o especially at the region of punch corner radius of the simulated cup.
2. The value of folding angle is equal to 354° for the second stage which is larger than the first one as a consequence of forcing the material to flow in the reverse direction resulting in more deformed and hence wider wrinkled region.
3. Greater stresses have been observed on the bottom of the reversely drawn cup higher than those for the first stage cup as a result of altering the drawing direction which accumulates the stresses in this zone.
4. Effective strains that have been generated in the second stage are larger than those induced in the first stage as the drawing ratio becomes higher requiring more stretching to perform drawing.
5. The maximum load predicted for the first and second stage is 24.244 KN and 26.933 KN

respectively. However, an average of fluctuating loads within the second stage can be taken to make the maximum load value closer to that of the first stage.

## REFERENCES

[1] A. R. Joshi, K. D. Kothari and Dr. R.L. Jhala "Effects of Different Parameters on Deep Drawing Process: Review" International Journal of Engineering Research & Technology, Vol. 2, Issue 3, pp. 1-5, 2013.

[2] Adnan I. O. Zaid and Fadhil A. Hashim "Effect of Punch and Die Profile Radii on Deep Drawing of Galvanized Steel" International Journal of Scientific & Engineering Research, Vol. 8, Issue 1, pp. 1209-1213, 2017.

[3] Masoud Kardan, Ali Parvizi and Ali Askari "Influence of process parameters on residual stresses in deep-drawing process with FEM and experimental evaluations" Journal of the Brazilian Society of Mechanical Sciences and Engineering, Vol. 40, Issue 157, 2018.

[4] D.M. Neto, M.C. Oliveira, J.L. Alves & L.F. Menezes "Influence of the plastic anisotropy modelling in the reverse deep drawing process simulation" Materials and Design, Vol. 60, pp. 368-379, 2014.

[5] S. Thuillier, P.Y. Manach, L.F. Menezes & M.C. Oliveira "Experimental and numerical study of reverse re-drawing of anisotropic sheet metals" Journal of Materials Processing Technology, Vols. 125–126, pp. 764–771, 2002.

[6] Z.Keran, M. Skunca & M. Math "Finite Element approach To Analysis Of Axisymmetric Reverse Drawing Process" METALURGIJA, Vol. 45, No.4, pp. 341-346, 2006.

[7] S.D. Zhao, Z.Y. Zhang, Y. Zhang & J.H. Yuan "The study on forming principle in the process of hydro-mechanical reverse deep drawing with axial pushing force for cylindrical cups" Journal of Materials Processing Technology, Vols. 187–188, pp. 300–303, 2007.

[8] Roberto Bortolussi, Sandro G. Solosando, Luis F. M. Martins & Ricardo B. Árias "Simulation of reverse deep drawing of cylindrical cups" V Congresso Brasileiro de Engenharia de Fabricação, 1 4 a 1 7 de abril de 2009, Belo Horizonte MG.

[9] Raman Goud. R, Eswar Prasad. K & Swadesh Kumar S. "Redrawing of EDD steel at elevated temperature" Advanced Materials Manufacturing & Characterization, Vol. 4, Issue 1, pp.75-80, 2014.

[10] Dr. Kariem M. Younis, Adil S. Jaber & Ammar M. salah " Numerical Analysis of The Multi-Stage Reverse Deep Drawing Process" Eng. & Tech. Journal, Vol. 34, Part (A), No.3, pp. 613-622, 2016.