Effect of Blank Holder Force on Strains and Thickness Distribution in Deep Drawing Process

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ABSTRACT

This work aims to study the effect of the blank holder force on strains and thickness distribution along cup wall of drawn part in deep drawing process. 2-D model of cylindrical cup of (40mm) outer diameter, and (0.5mm) thickness made from low carbon steel (1008–AISI), has been developed. A commercially available finite element package (ANSYS14.0) was used to perform the numerical simulation of deep drawing process. The experimental work carried out using digital image processing technique. Five values of blank holder force (F_{bh} =5, 7.5, 10, 12, 15 KN) were adopted. The numerical results of this model were compared with experimental results and the results show that, the value of the thickness and hoop strain at cup rim decrease with increasing blank holder force, while radial strain increases with increasing blank holder force. The best thickness distribution over all zones in produced cup obtained when using blank holder force with value (F_{bh} =10 KN).

Keywords: Deep Drawing, strain distribution, blank holder force.

تأثير قوة ماسك الغفل على توزيع الانفعالات والسمك في عملية السحب العميق

يهدف هذا البحث إلى دراسة تأثير قوة ماسك الغفل على وتوزيع الانفعالات والسمك على جدار القدح في عملية السحب العميق .تم المحاكاة باستخدام نموذج ثنائي الإبعاد لكأس اسطواني بقطر خارجي (40mm) وسمك جدار(0.5mm) من فولاذ منخفض الكربون (1008–AISI) وذلك باستخدام طريقة العناصر المحددة باستخدام برنامج (ANSYS 14.0). والعمل التجريبي نفذ باستخدام ألمعالجه الصورية حيث تم اعتماد خمسة أنواع من قوة ماسك الغفل (F_{bh} =5, 7.5, 10, 12, 15 KN). ومن مقارنة النتائج المستحصلة من خلال المحاكاة مع نتائج العمل التجريبي بينت النتائج العملية و المحاكاة أن قيمة انفعال السمك والانفعال المحيطي في منطقة حافة القدح تقل بزيادة قوة ماسك الغفل بينما الانفعال

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النصف القطري يزداد بزيادة قوة ماسك الغفل كما اظهرت النتائج العملية و المحاكاة أن أفضل توزيع للسمك على جدار القدح تم الحصول عليه بقوة ماسك غفل ذو قيمه ($\boldsymbol{F_{bh}}$ = 10 KN) .

INTRODUCTION

In the deep drawing process, there are many factors that affect the quality of product such as the Blank Holder Force (F_{bh}), the friction and lubrication conditions at the interface, and the die geometry. Among these factors, F_{bh} plays a key role in the flow of material. In most cases, a constant F_{bh} is applied over the punch stroke. A lower F_{bh} will cause wrinkling due to excessive material flow into the die. In order to prevent thickening, a higher F_{bh} needs to be applied. A higher F_{bh}, however, can lead to thinning, thus, it is important to determine the appropriate constant F_{bh} over the punch stroke [1].

Since a number of investigators have studied the drawing process, the current exposition here will focus only on the researches concerning the control of blank holding force will be an effective way to prevent thinning and wrinkling in deep drawing.

N. Krishnan and **Jian** [2], paper followed a strategy to optimize the blank holder force history to maintain predetermined wrinkling amplitude under the blank holder. **C. Esner and M. Yasar** [3], investigated the impact of the blank holder pressure (P_{ph}) on wall thickness, cup depths, tearing and wrinkling in deep sheet drawing process. The results show that, the blank holder pressure increases from (0.5Mpa-25Mpa), it is observed that wall thickness of cups drawn gets thinner towards the punch profile region and decreases in thickenings occur towards the cup edge and maximum value of thickness with blank holder pressure equal to (0.5Mpa). **R. Padmanabhan and M. C. Oliveira** [4] investigated the influence both variable and constant blank holder forces on the thickness distribution in the deep drawing of axi-symmetric cup using Finite Element Method. The numerical results show that, when using different blank holder force schemes, wall thinning occurs at the corner of the cup and thickening occurs near the top and at the flange. **A. Purushotham** [5] studied the influence of blank holding force on strain distribution in deep drawing process. The results show that, the radial strain increases with increasing blank holder force, but thickness decreases with increasing blank holder force at the rim of the cup. The study of the effect of using constant, variable and non-uniform blank holder force between the blank and blank holder on the thickness distribution, strain and stress along the cup (wall, base and nose) was carried out by **A. D. Younis** [6], The simulation results show that, the best value of blank holder force were achieved at Variable Non-Uniform type, which gives the smallest difference between maximum and minimum thickness distribution along the cup.

This paper aimed to study the effect of blank holder force on strains and thickness distribution along cup wall of drawn part in deep drawing process.

Numerical Simulation

A cup of (40mm) outer diameter, and (25mm) height, was chosen for detailed analysis of deep drawing operation. The blank from which it is formed has a diameter of (80mm), with (0.5mm) thickness and is made of low carbon steel of 0.08% carbon content, (200MPa) yield stress, (200GPa) Modulus of elasticity, (0.52GPa) Tangent modulus and of (0.3) Poisson's ratio. A commercial FE package (ANSYS 14.0) was used to simulate the deep drawing operation. Elasto-plastic behavior for work material was used in the simulation. The 2-D modeling of solid structures element of (VISCO106) was used for the blank. For rigid (tool set)-flexible (blank) contact, target elements of (TARGE169) were used, to represent 2D target (tool set) surfaces which were associated with the deformable of the bank represented by 2D contact elements of (CONTA171). The finite element model of the sheet material and drawing die is shown in Figure (1). A friction of coefficient with value (μ=0.1) was employed. Five different Type of blank holder force (F_{bh} =5, 7.5, 10, 12, 15 KN) were used. The clearance between punch and die was set to be (1.1 of sheet thicknesses). A successive final stage of the deep drawing sheet for radial and thickness strains are shown in figure (2 A and B) respectively.

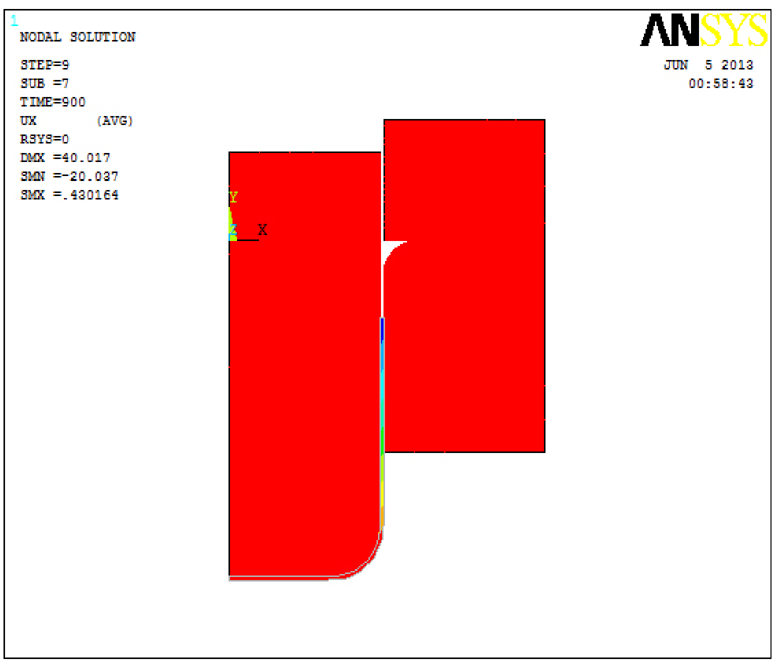

Figure (1) Finite element model of the sheet material and drawing die

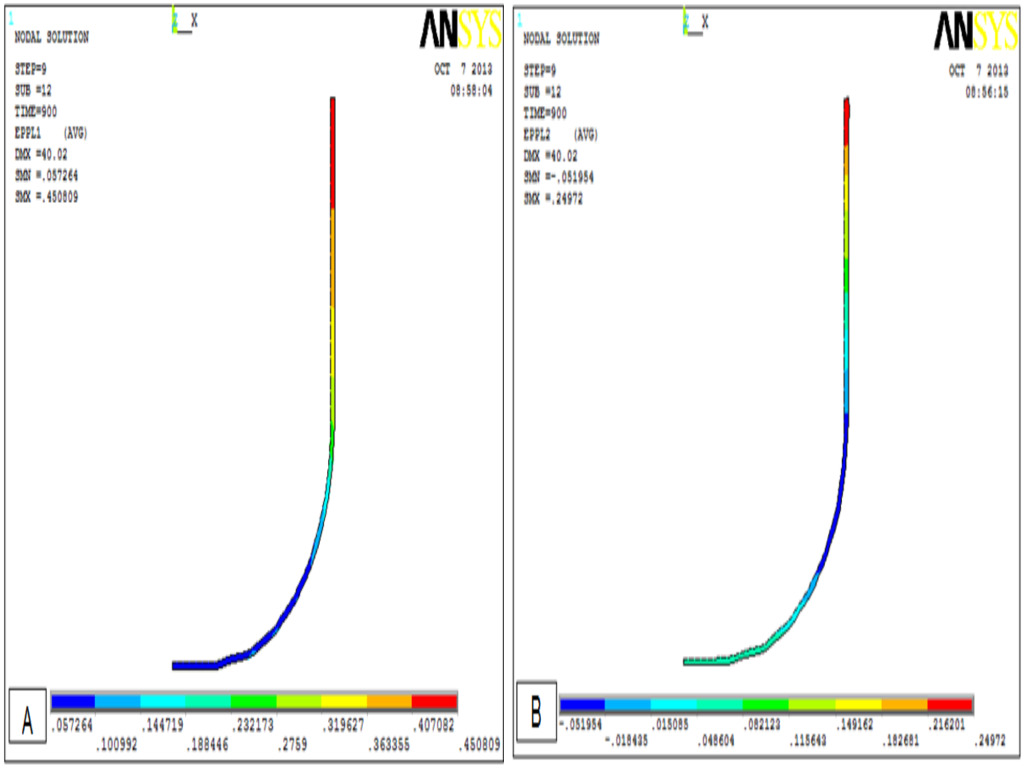

Figure (2) The strain distribution on cup wall of tool geometry, (A) radial strain, (B) thickness strain

Deep Drawing Experiment

Material Used

The characteristics of the material to be drawn have a great influence on the success of a drawing operation. Low carbon steel (1008–AISI) is chosen to carry out the work, where this type is used in many drawing application, such as cars bodies, storage tanks and other applications. A chemical composition test was carried out by using spectrometer device to check the manufacture certificate of materials is listed in Table (1).

Table (1) Chemical composition of low carbon steel (1008–AISI)

C%	Si%	Mn%	S%	P%	Cr%	Ni%	Mo%	V%	Cu%	Al%
0.08	0.02	0.32	0.024	0.014	0.035	0.032	0.002	0.001	0.072	0.044

Experimental Tooling

Deep drawing experiments were carried out to obtain cylindrical cups by mounting deep drawing die on the testing machine as shown in figure (3). The testing machine type (WDW-200E) which has a capacity of (200KN). The die set was mounted on a hydraulic press; the press is equipped with a computer which is reading the punch stroke and the punch load automatically by using load cell. Five different types of initial blank holder force (F_{bh} =5, 7.5, 10, 12, 15) KN), tool geometry (punch and die profile radius in mm) [R_p6R_d6] ware used. Drawing speed equal to (55mm/min) was selected to draw for low carbon steel.

After putting blank on the blank holder surface, die will drop towards the punch; this means inverted drawing die use. The produced cup has 25 mm height.

In order to study the strain distribution within the cup during drawing operation, the square grid is printed with dimensions of (2.5×2.5 mm) and a depth of about (0.1 mm) as shown in Figure (4) by using screen printing. The digital image processing technique (DIG) was used, it takes a picture of the grid on the sample before and after the deep drawing process, the Figure (5) shows the deformation of grid on samples after the deep drawing operation tests were performed. The image was obtained by using the digital camera (SONY DSC-W300) with a resolution of (4224 × 3168 Pixels). MATLAB Image Processing Toolbox was used to investigate the relative displacement and the surface strains by the use of distinct grid on the sample.

Radial strain and hoop (circumferential) strain distribution were derived from the measured dimensions grid square using the incompressibility condition by using the following equations (1) and (2), respectively and then thickness strain by using equation (3).

$$\epsilon_r = \ln \frac{a_1}{a_\circ} \quad \text{....(1)}$$

$$\epsilon_\theta = \ln \frac{a_2}{a_\circ} \quad \text{... (2)}$$

$$\epsilon_t = -(\epsilon_\theta + \epsilon_r) \quad \text{...(3)}$$

Where $a_\circ$ (mm) represents of grid square length before the deformation a_1 , a_2 represent grid square lengths after the deformation as shown in figures (4) and (5) respectively.

a_1 Major dimension grid square after the deformation (mm)

a_2 Minor dimension grid square after the deformation (mm)

With the assumption that the principal strain directions and the ratio of the incremental stain dϵ_r, dϵ_t and dϵ_θ remain constant; an equivalent strain (effective strain) (ϵ_{efff}) can be computed.

$$\epsilon_{eff} = \sqrt{\epsilon^2{}_t + \epsilon^2{}_r + \epsilon^2{}_\theta} \quad \text{...(4)}$$

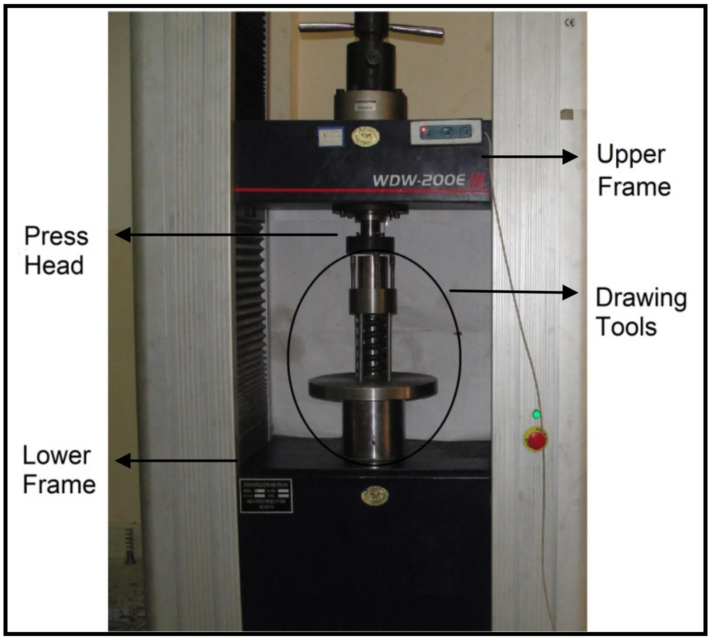

Figure (3) The assembly picture of tools and apparatus used

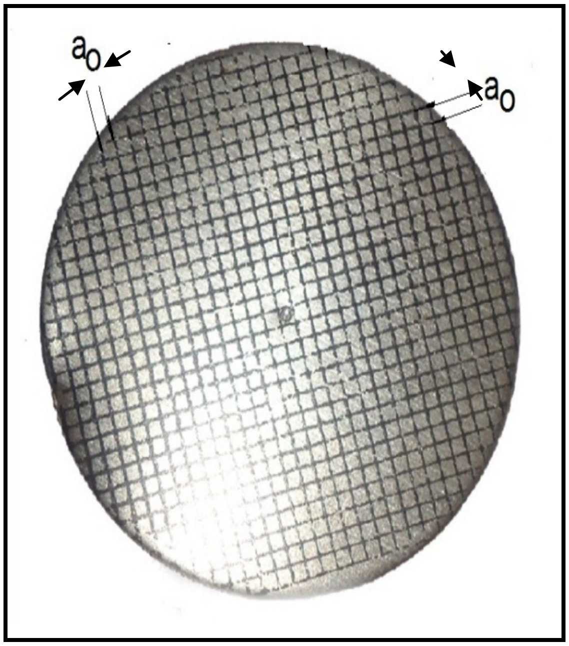

Figure (4) Blank with grid, by using screen printing

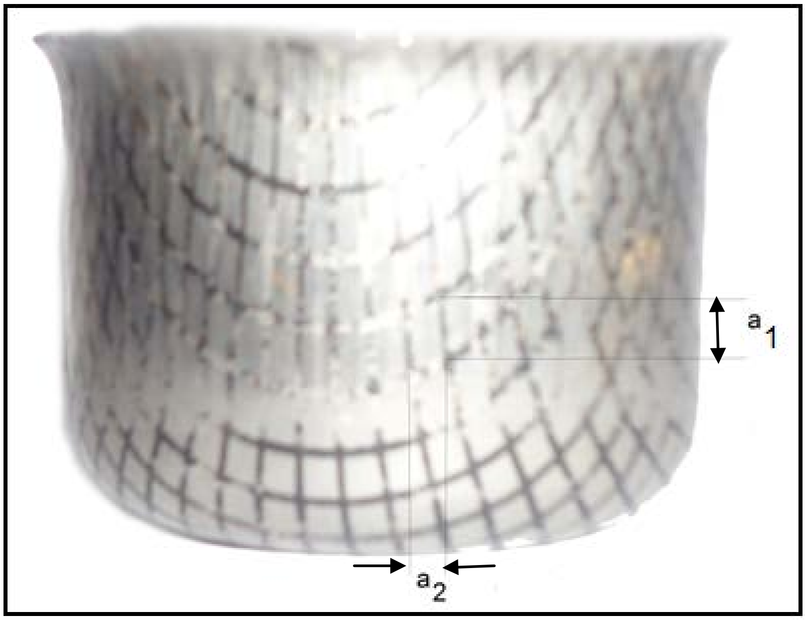

Figure (5) Distribution of grid square at the cup wall

Results and Discussions

In axi-symmetric deep drawing, the flange rim undergoes the most severe shrinkage during the process, and hence became thickest part of the flange. That is why the horizontal restraining force resulting from the friction between die / blank holder and the blank sometimes considered as being applied at the flange rim. In order to check the validity of this assumption we considered five different value of initial blank holder force (F_{bh} = 5, 7.5, 10, 12, 15 KN) exerted by blank holder on the flange.

Effect of blank holder force on thickness distribution

Figure (6) shows the effect of blank holder force on cup wall thickness. It is clear from the figure that, thickness remains constant under punch face (cup bottom), resulting from the flat face of the punch in contact with blank, and because the drawing force, friction plays a role preventing any deformation in the metal under the punch, hence there is no changing in thickness. At The punch corner, the thinning will occur because of stretching exerted by tensile stress and also increases with increasing blank holder force. Afterward the cup wall thickness tends to increase, and this is caused by compressive stress applied to this region. At the end of cup wall it is clear the thickness decreases with increasing blank holder force. It is noticed that, the best thickness distribution over all zones in produced cup is obtained when using blank holder force with value ($\boldsymbol{F_{bh}}$ =10 KN).

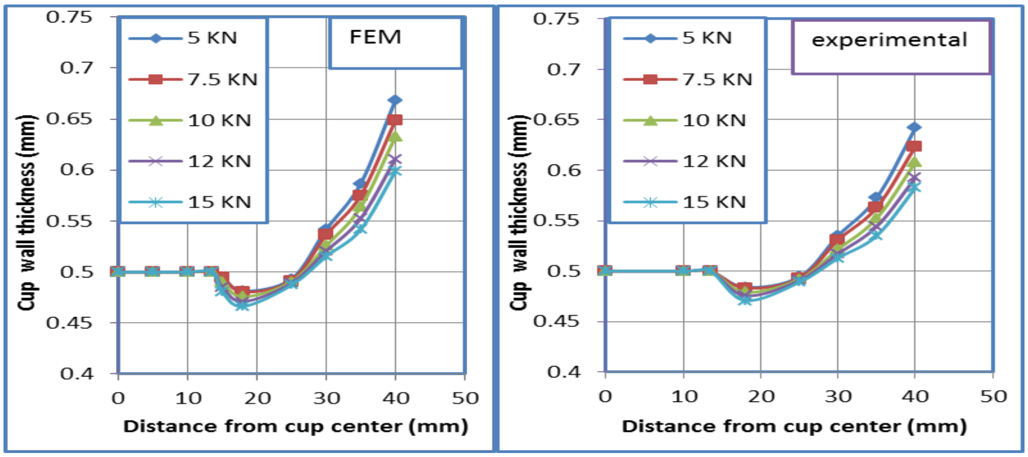

Figure (6) Effect of blank holder force on thickness distribution

Effect of blank holder force on radial strain along the cup

Figure (7) shows the radial strain over the cup wall of the completely drawn part. It is obvious from the figure that, the radial strain (ϵ_r) under cup bottom is zero, since no deformation occurs in this areas then will increase suddenly at punch corner and continues until the end of cup wall to reach a maximum value at the cup rim due to tension in this direction and this value increases with increasing blank holder force and maximum value with larger blank holder force equal to (F_{bh} = 15 KN).

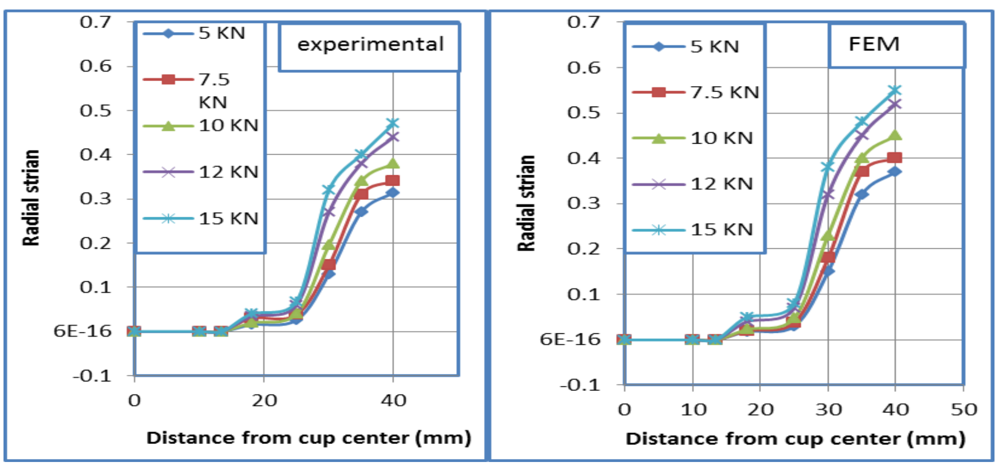

Figure (7) Effect of blank holder force on radial strain

Effect of blank holder force on thickness strain along the cup

Figure (8) represents the effect of blank holder force on the thickness strain(ϵ_t). It is clear from the figure that, the thickness strain at the cup bottom is zero, due to friction which prevents any deformation of the metal under the punch head, and hence no thickness change is observed, afterward the cup corner the value of thickness strain becomes negative (reduce in thickness) as a result from tension stress in this area and the maximum reduction occurs at the larger blank holder force equal to (F_{bh} = 15 KN), then becomes a positive at the cup wall (increase in thickness) because of compressive stress in this direction and continues to increase to reach maximum value at the end of cup wall and decreases with increasing blank holder force and maximum value with smaller blank holder force equal to (F_{bh} = 5 KN).

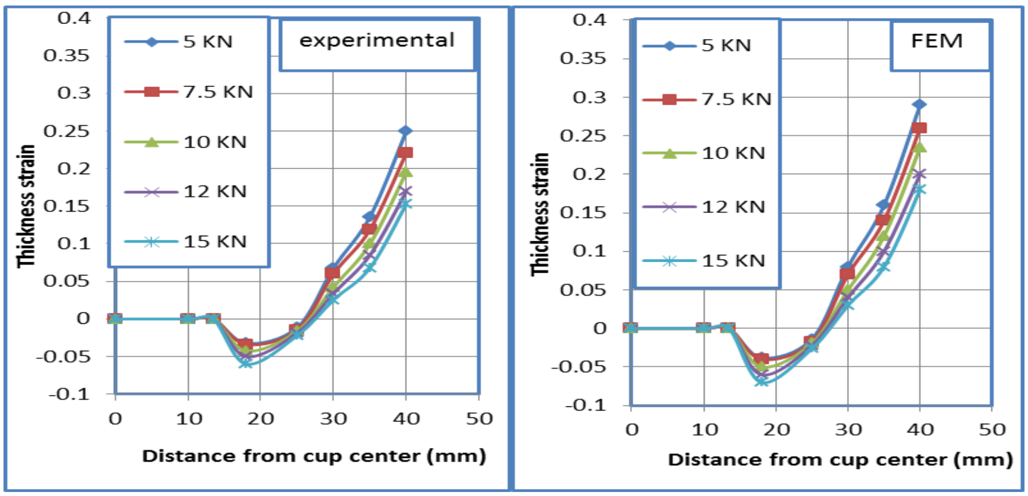

Figure (8) Effect of blank holder force on thickness strain

Effect of blank holder force on hoop strain along the cup

Figure (9) represents the effect of blank holder force on hoop strain (ϵ_θ). It is seen from the figures that, 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 area, then begins to decreases towards cup wall to have negative value (diminishes in circumference) because of the compression applied in this direction and it continues to decrease to reach a maximum value at the end of cup wall and this value decreases with increasing blank holder force and maximum value with smaller blank holder force equal to (F_{bh} = 5 KN).

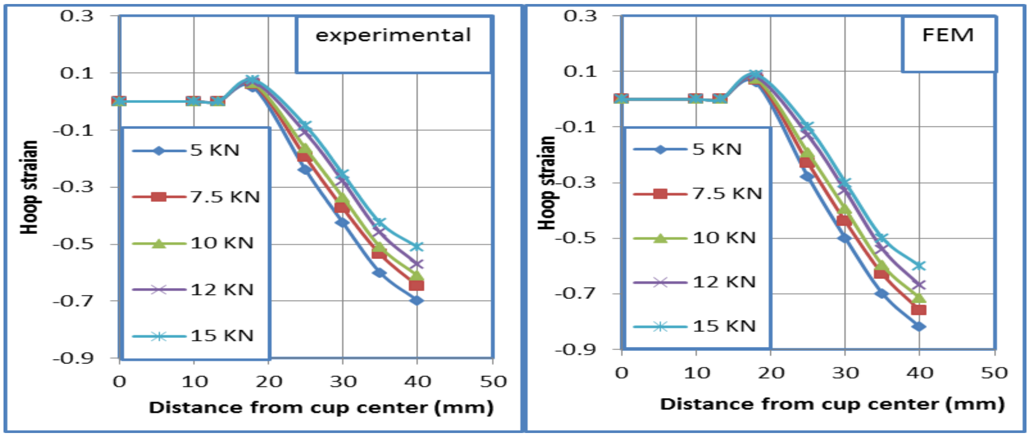

Figure (9) Effect of blank holder force on hoop strain

Effect of blank holder force on effective strain along the cup

Figure (10) represents the effect of blank holder force on the distribution of equivalent (effective) strain (ϵ_{eff}) over the cup wall. It is obvious from the figure that, the value of equivalent (effective) strain is zero at cup bottom where very small deformation occurs in this area which cannot be observed and then there is some rise at the latter region (cup corner) because severe deformation (severe bending) in this region. Afterward the cup wall effective strain continues to increase to reach a maximum value at the end of cup wall and this value decreases with increasing blank holder force and maximum value with smaller blank holder force equal to (F_{bh} = 5 KN). It is noticed that, the best strain distribution over all zones in produced cup obtained when using blank holder force with value (F_{bh} =10 KN).

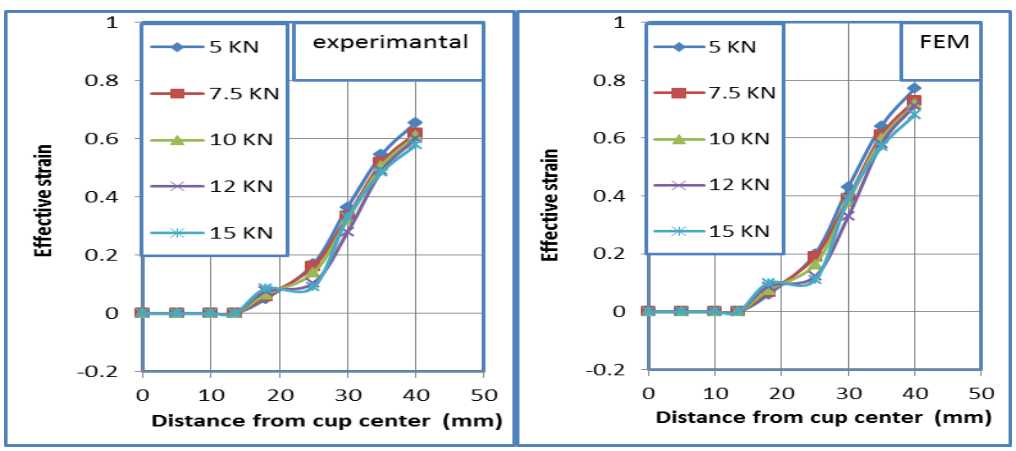

Figure (10) Effect of blank holder force on effective strain

CONCLUSIONS

1. The maximum thinning occurs at region of cup corner and increases with increasing blank holder force, while the thickening at the end of cup wall decreases with increasing blank holder force.
2. The best thickness distribution over all zones in produced cup obtained when using blank holder force with value $(F_{bh}$ =10 KN).
3. The radial strain at region of the end of cup wall increases with increasing blank holder force
4. The thickness, hoop and effective strain at region of cup rim decreases with increasing blank holder force
5. it is seen that the more uniform strain distribution over all zones in produced cup obtained when using blank holder force with value $(F_{bh}$ =10 KN).

REFERENCES

[1] Simoes, V. M., “Analysis of the influence of process parameters in the deep drawing of cylindrical cup”, M. Sc., thesis, University of Coimbra, 2012.

[2] Krishnan, N., “Three dimension numerical simulation in deep draws”, M.Sc., Thesis, Queen's University, 1998.

[3] Demirci, H. Ù., Esner, C. and Yasar, M., “Effect of the blank holder force on drawing of aluminum alloy cylindrical cup: theoretical and experimental”, Kumamoto University, Japan, Vol. 20, ISSUES 1-2, 2008.

[4] Padmanabhan, R. and Oliveira, M. C., “Numerical simulation and analysis on the deep draw”, University of Coimbra, Portugal, pp. 423–416, 2008.

[5] Purushotham, A., “Simulation studies on deep drawing process for the evaluation of stresses and strains”, Sree Nidhi Institute of Science & Technology, Ghatkesar, Hyderabad, India, Vol.03, Issue 4, 2013.

[6] Younis, A. D., “The effect of using non-uniform blank holder force in deep drawing process on the thickness distribution along the cup”, University of Mosul, Iraq, Vol.21, No. 2, 2013.