The effect of using Non-Uniform Blank Holder Force in Deep Drawing process on the thickness distribution along the cup

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Abstract

In this paper, a new concept of blank holder in deep drawing is presented. The aim of this study is to predict the wrinkling and thinning (necking) failure through the study of the effect of using constant, variable and non-uniform blank holder force(**BHF**) between the blank and blank holder on the thickness distribution along the cup (wall, base and nose). Numerical modeling were carried out on various values of blank holder force **(BHF)** (i.e., Constant-Uniform, Variable-Uniform, Constant Non-Uniform and Variable Non-Uniform). The simulation results shows 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.

Key wards: ANSYS 11, Deep Drawing, Blank holder force

تأثير استخدام قوة مثبت الغفل الغير منتظمة التوزيع في عملية السحب العميق على توزيع السمك على طول الكأس

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الخلاصــــــــة

قي هذا البحث تم دراسة مفهوم جديد لمثبت الغفل في عملية السحب العميق. الهدف من هذا الدراسة هو التوقع للفشل نتيجة التجعد والتنحيف (التعنق) من خلال دراسة تأثير استخدام قوة مثبت الغفل عامل متغير, حيث تم أخذها (ثابتة ومنتظمة، متغيرة ومنتظمة، ثابتة وغير منتظمة التوزيع على طول الغفل ومتغيرة وغير منتظمة التوزيع على طول الغفل) بين الغفل ومثبت الغفل على توزيع السمك على طول الكأس (الجدار, القاعدة والحافة). تم استخدام دراسة رقمية لقيم متغيرة من قوة مثبت الغفل, حيث تمت المحاكاة باستخدام برنامج هندسي واستخراج النتائج, وقد بينت النتائج إن أفضل توزيع للسمك على طول الكأس هو عند استخدام قوة مثبت الغفل المتغيرة والغير منتظمة التوزيع على طول الغفل.

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1. Introduction

The quality of deep drawn products is highly dependent upon the rate at which the sheet is drawn into the die. It is necessary to optimize the restraining forces applied to the blank for a given blank shape, material and final part geometry. For non-symmetric parts that have non-uniform material properties, the optimization of the (**BHF)** requires that the pressure distribution on the blank be varied spatially and as a function of time or press ram position [**1**].

Excessive metal flow will cause wrinkles in the part while insufficient metal flow will result in tears or splits. The blank holder plays a key role in regulating the metal flow by exerting a predefined (**BHF**) profile. When selected properly, this **(BHF)** profile can eliminate wrinkles and delay fracture in the drawn part [**2**].

Usually, in deep drawing, a constant **BHF** is applied over the punch stroke. During the drawing process, the state of stress in the deforming material changes significantly. Consequently, the process conditions that reduce wrinkling and fracture also change. To take into account these changes, it is reasonable that the **BHF** should also be modified to increase the formability of the drawn part. To further improve the formability when drawing complex parts, an elastic or segmented blank holder can be used to obtain a non-uniform **BHF** over the part flange area. Thus, it is possible to account for variations of the blank holder surface [**3**].

The incentive for doing this research is that deep drawing has come to a stage in the current industrialized world that requires the most efficient, low-cost, manufacturing route to be taken at all times [**4**].

The general opinion in the automotive industry is that improvement may be achievable in some components by introducing a variable **BHF** [**5**]. The finite element analysis (**FEA**) and numerical simulations are usually carried out under the working conditions specified by the users. The users repeat the simulation by changing the conditions until an a acceptable result or an optimized one is reached. It may be possible to reduce users efforts by setting an appropriate condition during the numerical simulation [**6**].

Blank holding

Blank holding principally aims at preventing wrinkling. The two methods used for blank holding are [**7-9**]:

1. Clearance blank holding (fixed blank holding).
2. Pressure blank holding.

Clearance blank holding maintains a fixed clearance which may resist anticipated thickening at some stage of drawing. 5% clearance is practically sufficient to resist wrinkling but does not avoid development of a stretching region.

Pressure blank holding can provide a varying blank holding force and at the same time restrain some of the thickening of the rim.

Blank holding force produces a frictional force resisting the radial movement towards the die orifice, thus increasing the load acting on the wall.

2. Numerical Simulation Modeling

In deep drawing, numerical simulations have been widely used to assist parts and process design by:

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

Solid elements, shell elements and membrane elements are three main types of finite elements that can be used in finite element modeling of the blank and tooling elements, the elements of the forming tools are usually intended to impose the forming loads to the sheet metal through the forming interface. Due to the fact that the forming tools should be, theoretically, designed to be rigid and the die-face deformations should be elastic with minimal shape changes, only the surface geometry of the forming tool are generally included in the process simulation **[2]**.

In this work the commercial FEM code (ANSYS 11) are used to simulate the process of Non-uniform distribution of blank holder force in deep drawing operation. Cup forming was created and the numerical results were compared with the uniform distribution of blank holder force results. When placing the parts in the system, the direction and the values of wall thickness were taken into consideration. Mild steel sheet was used, with the mechanical properties, shown in table (1). Figure (1) Show the modeling system is composed of the press, blank holder, blank (sheet metal) and die. This cup without flange, and completely drawn into the die shown in figure (2) and (3).

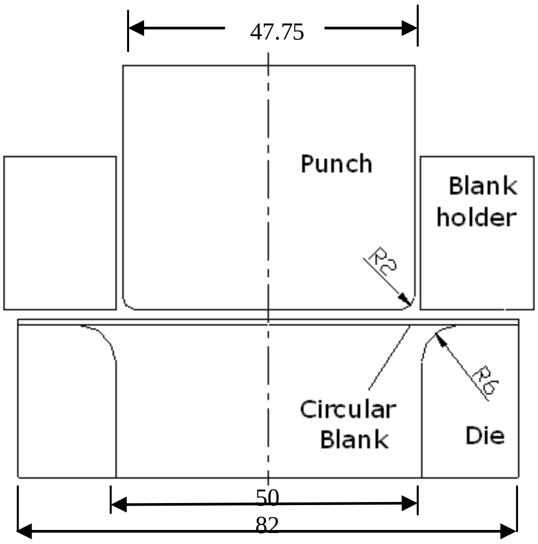

Figure (1) Geometry of the tools used in this study

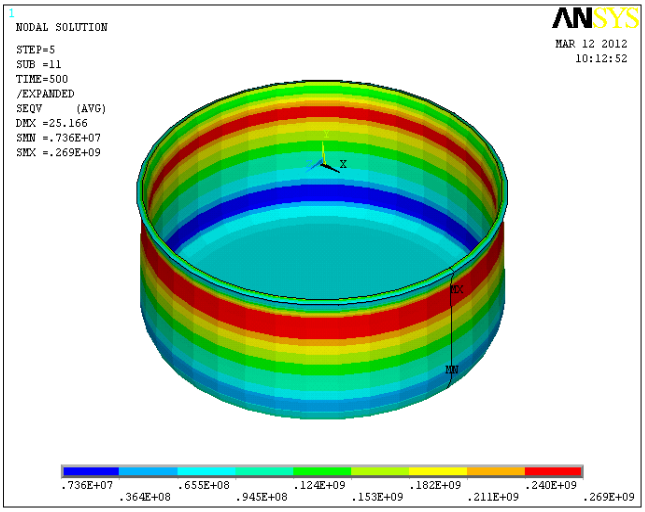

Figure (2) 360 2-D axisymmetric symmetry expansion of the deformed

The punch, die and the blank holder represented by element type (Target 169), which defined by three nodes having two degrees of freedom at each node. The blank material represented by element type (Visco 108), which defined by four nodes having up to three degrees of freedom at each node. The contact interface between die and the deformed material is represented by element type (Contact 171), which has two degrees of freedom at each node. Figure (4) shows the meshing for the model.

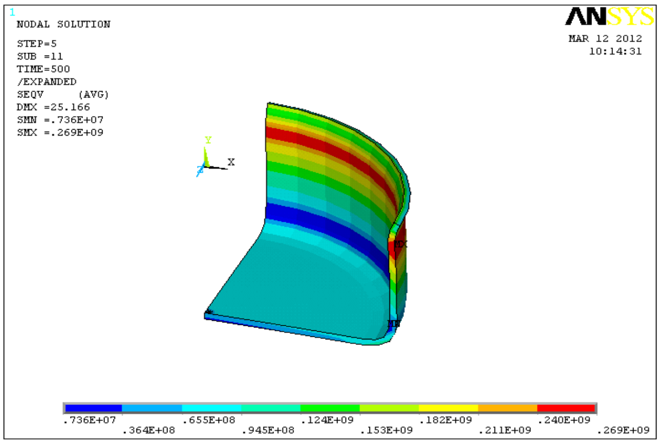

Figure (3) 90o 2-D axisymmetric symmetry expansion of the deformed cup

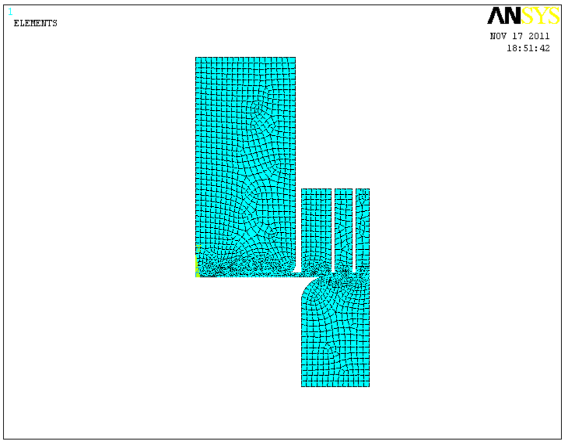

Figure (4) finite element model

The loading was conducted in the form of a prescribed displacement. The total travel of punch was (y=40mm). Isotropic Hardening Plasticity model was used, the plastic response was modeled using the Von Mises Yield Criterion, with the material properties listed in Table-1-.

Table -1- Mechanical Properties

Initial Thickness to (mm)	Mechanical Properties of mild steel sheet				
	Tangent Modulus of Elasticity ET (GPa)	YS (MPa)	E (GPa)	Poisson's Ratio	Coefficient of Friction μ
1	0.5	190	200	0.3	0.05

Description of the types of Blank Holder Force

1. Uniform-load constant (BHF). In constant BHF the force remains constant when the punch is moving down.

2. Uniform-load variable (BHF). The load is the same as distribution in figure (5) but the meaning of variable BHF is; the force increases (changes) during the punch is moving down.

3. Non-Uniform load constant (BHF). The Non-Uniform (BHF) (shown in figure 6). The BHF is remained constant during the Punch is moving down.

4. Non-uniform load variable (BHF).The load distribution is the same as in figure (6) and the BHF increases (Changes) during the punch moving down.

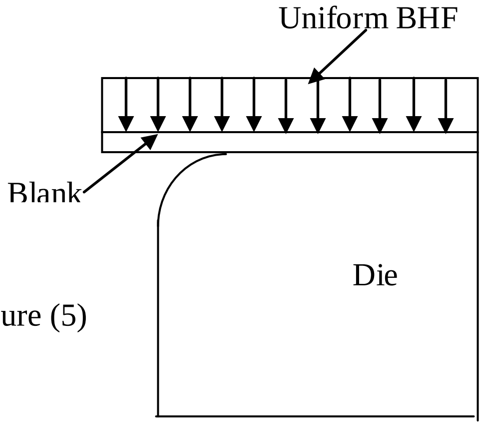

Figure (5)

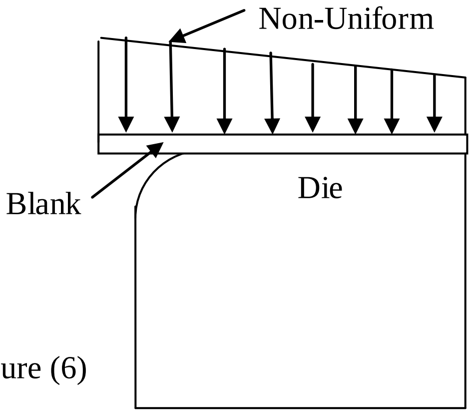

Figure (6)

3. Results and discussion

In this paper, different blank holder forces were used by taking different cases, such as constant **BHF(UC)**, variable **BHF(UV)**, constant Non-Uniform **BHF(NUC)** and variable Non-Uniform **BHF(NUV)** (which listed in table -2-) and their effects have been explained and discussed during Deep Drawing process.

Table -2-Blank Holder Force Distribution

	Term meaning	Beginning of flange(start of edge die)	middle of flange(middle of edge die)	end of flange(end of edge die)
UC	uniform distribution constant blank holder force along the flange	100 KN	100 KN	100 KN
UV	uniform distribution variable blank holder force along the flange	100-150-200-250-300 KN	100-150-200-250-300 KN	100-150-200-250-300 KN
NUC	Non-uniform distribution constant blank holder force along the flange	300 KN	150 KN	25 KN
NUV	Non-uniform distribution variable blank holder force along the flange	100-150-200-250-300 KN	50-100-150-200 KN	10-50-100 KN

3.1.The effect of BHF on (wall, base and nose) thicknesses

The effect of **BHF** on the (wall, base and nose) thicknesses of mild steel sheet was examined in Figure.7. To investigate the effect of values of **BHF** on the deep drawing process, four values of **BHF** were chosen for the simulation of deep drawing operation.

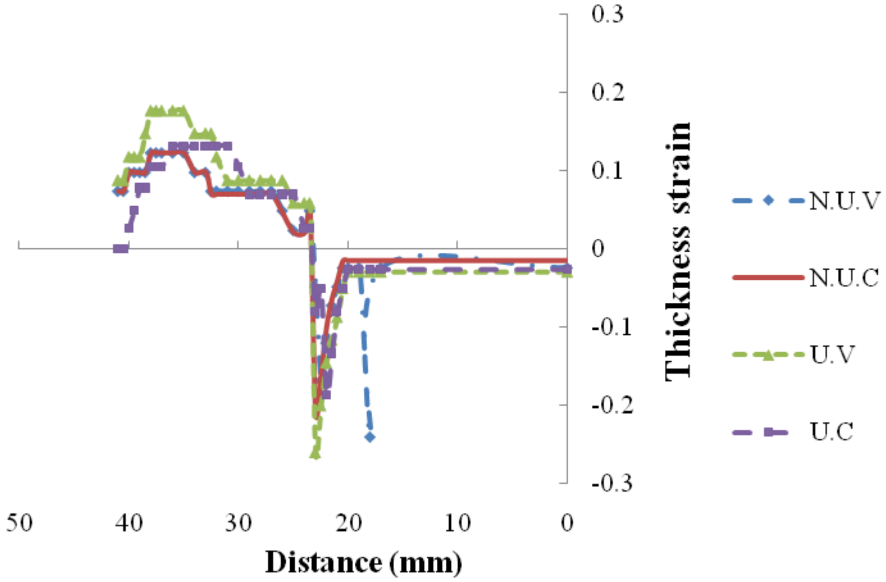

Figure (7) Thickness strain distribution along the cup

Figure (7) shows the relationship between the thickness strain in the cup and the distance from cup center. The thickness approximately is constant under the punch base, and then increases on the cup wall until a maximum value obtained at the end of the cup wall. The hoop stress (circumference) tends to thicken the blank in the end of the cup wall. Both friction and stretch will occur over the punch nose, the blank thinning near the punch base. The lowest variation between the maximum and minimum thicknesses is found at Non-Uniform variable **(NUV) BHF** (i.e., 16.8% thinning and 12.3% thicking). The variation in Non-Uniform constant **(NUC) BHF** is 21% thinning and 9% thicking, for Uniform variable **(UV) BHF** is 26% thinning and 17.7% thicking and for Uniform constant **(UC) BHF** is 18.6% thinning and 13.1% thicking.

3.2.The effect of BHF on effective strain

Figure (8) shows the relationship between the effective strain and the distance from cup center, the difference in the effective strain is higher near the center radius (under punch) because of the equal biaxial tension and gradually decrease as moving further from the center until it reaches the end of the cup wall (i.e. where all curves are meeting at a single point).
The maximum thickness strain values were achieved with **UV BHF** and the minimum value with **NUV BHF**.

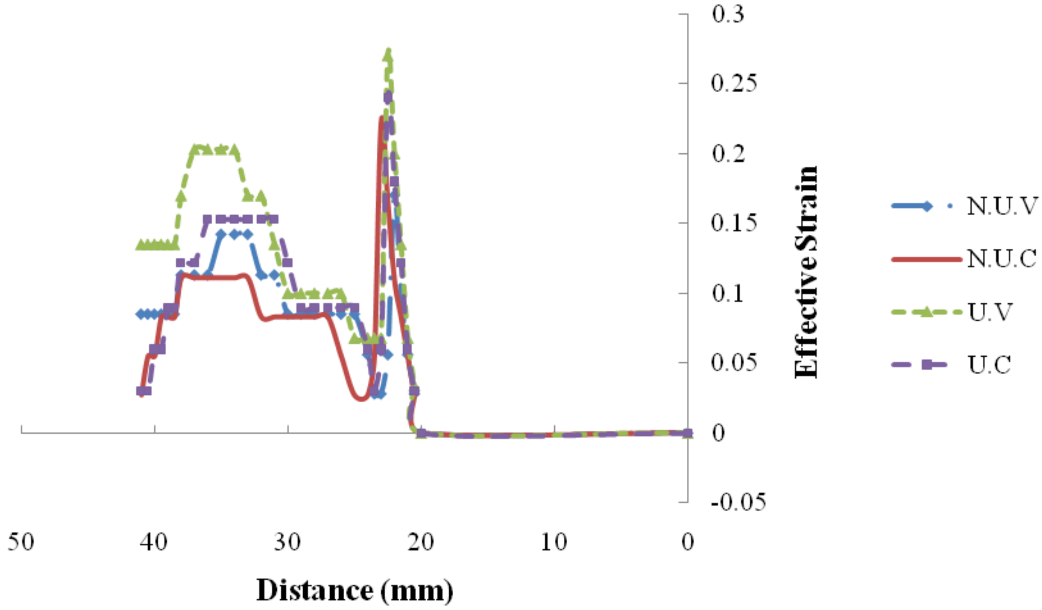

Figure (8) the effect of **BHF** on effective strain

3. 3 .The effect of BHF on effective stress

Figure (9) shows the relationship between the effective stress and the distance from cup center, where the four cases of **BHF** are behaving uniformly and approximately similar. The effective stress has almost low constant value under the punch base because there is no forming under the punch base. The effective stress increase on the cup wall until it reaches the maximum at the end of the cup wall.

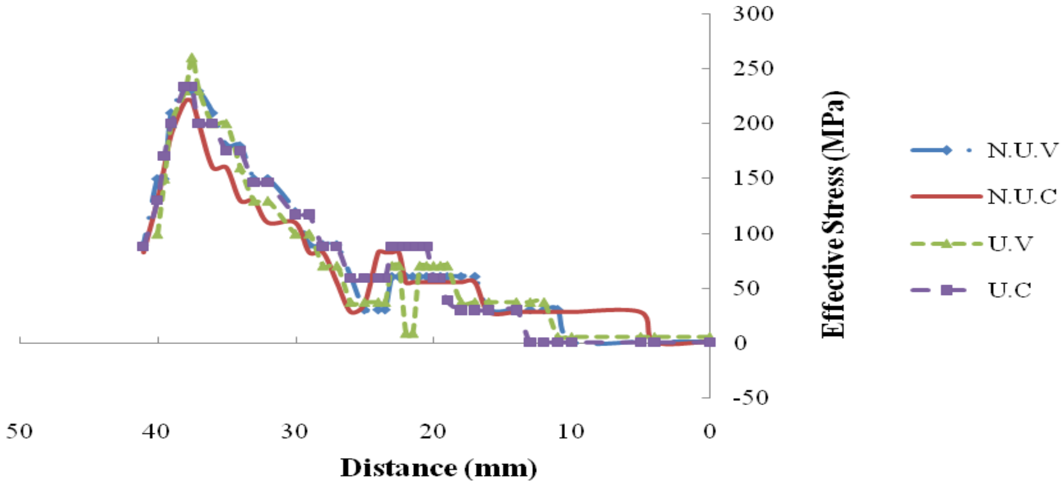

Figure (9) the effect of **BHF** on effective stress

4. Conclusion

Determination of an optimal **BHF** for producing a cup without defects in axi-symmetric deep drawing of steel sheet was studied though FEM simulations. It can be concluded that the simulation method can predict an optimum **BHF** for cup drawing process. The results show that the best **BHF** profile is Non-Uniform variable **BHF**, which can improve the uniformity of the cup thickness distribution in deep drawing.

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