EFFECT OF BLANK HOLDER TYPE ON DEEP DRAWING OF CUPS

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ABSTRACT

The purpose of this study is to examine the change in the wall thickness of drawn cup by using fixed blank holder gap (BHG) and variable blank holder force (BHF) to hold the sheets metal during drawing operations. The effect of BHG and BHF on drawn cups was studied by the experimental and theoretical approach. Two blank holder gap, BHG = 0.5, and 1 mm and variable blank holder force were used in the experiments. The study shows that a type of blank holder has a great effect on the quality change of the wall thickness of the final product, and BHG and BHF are considered important parameter to control material flow.

Punch and die with diameters 43mm, 44 mm respectively are used to draw low carbon steel sheet (1008-AISI) with a thickness of 0.5 mm to draw a (cylindrical cups) from blanks with different reductions 0.5,0.55, 0.6, 0.65, and 0.7.

The punch and die have the profile radius 4mm.

Press with a maximum load capacity of 200 KN with speed 10 mm/mint was used to perform this research.

The results show that no change occurs in the thickness of cups at ρ = 0.6 R, radius of blank, whereas the maximum change (thickening) of the wall thickness occurs when ρ = R, and the minimum value (thinning) of wall thickness in the corner of the cup. All values which estimated theoretically are slightly different for measured experimentally. The best results were obtained from the BHG = 0.5 mm compare to BHG = 1mm and BHF.

Keywords: deep drawing, blankholder gap, blankholder force, thinning, and thickening.

تأثير نوع ماسك الغفل في عملية السحب العميق

ألخلاصة:

ألغرض من هذه الدراسة هو الكشف عن التغير في سمك جدار الوعاءالمسحوب باستخدام ماسك الغفل ذو الفجوة الثابتة BHG و استخدام نابض متغيرالقوة BHF لمسك الغفل المأخود من صفيحة معدنية خلال عمليات السحب.

تمت دراسة تاثير BHF و BHG لوعاء دائري عمليا ونظريا من خلال فجوتان 1ملم و 0.5ملم ، و BHFمتغير القوة.

بينت الدراسة ان نوع ماسك الغفل له تاثيرا كبيرا على نوعية التشكيل للجزء النهائي حيث يعتبر BHF و BHG من الوسائل المهمة للسيطرة على انسياب المعدن.

يتألف قالب السحب الذي تم تنفيذ العمل به من خرامة و فتحة سحب بأقطار 43و 44 ملم على التوالى لسحب اوعية اسطوانية من اغفال مأخودة من صفائح الصلب المنخفض الكربون (AISI-1008) وبسمك 0.5 ملم بمختلف التخصرات0.5 ,0.55, 0.7,0.65,0.6 وأن انصاف اقطار تقوس القالب هي 4 ملم (للخرامة و لفتحة السحب).

السعة الكلية للمكبس المستخدم لتنفيذ الاختبارات هى 200كيلو نيوتن و بسرعة 10ملم/دقيقة.

بينت االنتائج عدم تغير سمك المنتج عند مسافةρ=0.6Rبينما اكبرتغير في السمك (تضخم) يحصل عند مسافةρ=R وأن اقل قيمة للترقق في سمك الجدار تحصل عند اركان الوعاء السفلية. اغلب القيم المخمنة نظريا تختلف بشكل طفيف عن القيم المقاسة عمليا.

افضل النتائج تم الحصول عليها باستخدام فجوة ماسك الغفل الثابت (BHG) مقدارها (0.5 mm) بالمقارنة مع الماسكين الاخرين واللذين هما ماسك الغفل (BHG) ذو الفجوةالثابته التي مقدارها (1mm) وماسك الغفل المتغيرالقوة (BHF).

INTRODUCTION

Deep drawing is a sheet metal forming process in which a sheet metal blank is radially drawn into a forming die by the mechanical action of a punch **Marciniak, Z. L. Duncan 2002**. **Fig. 1** shows sketch of punch, die, blank holder, and blank.

The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter. The compressive stresses (hoop stresses) result wrinkles in flange (wrinkles of the first order). Wrinkles can prevent by using a blank holding force (BHF) or blank holder gap (BHG). The blank holder type is important parameter to control the success or failure of a deep drawing operation. Blank holding force (BHF) with variable force and blank holder gap (BHG), which defined as the distance between the blank holder and die surface **Cao J. MC. Boyce, 1997 and Thung SY. 1999**. The change of wall thickness through the different sections of cup shaped-part in a single step (in one pass) are very important to give clear idea about process. If the shape-change required by the part design is to sever (drawing ratio is to high), complete forming of the part may required more than one drawing step this is achieved by redrawing or reverse drawing the part through a series of dies. Our discussion has focused on a cup drawing operation that produce in a single step a cylindrical shape and uses a blank holder to facilitate the process. In the field of deep drawing many experimental and research works have been published. The results were claimed to be sufficiently accurate to provide a basis of reference for theoretical treatments of cup drawing, as well as an empirical basis of comparison between different drawing conditions **Chu E., Xu Y. 2001, Lihui L., Jocahim D., Karl BN. 2004, and Meguid SA, Refaat**

MH. 1997. As will as the parameters which control of a deep drawing process such as the anisotropy and drawability of workpiece material, also the mechanics of plastic deformation, the condition of the tool–workpiece interface , drawing ratio, punch and die profile radii, punch–die clearance, punch speed, and blank thickness were studies by **Browne MT. 2003, and Liu G.Lin Z., Bao Y. Cao J. 2002.**

Inserted piece of thin brass sheet between the rim block and the blank holder to adjust the value of BHG between the blank-holder and die by **Lang L., Danckert J., Nielsen KB. 2004.**

Experiments and FEM-simulations show that by using tractrix shaped die profile through stages drawing process a substantial increase in the straightness of the cup wall and a substantially decrease in the residual stresses can be achieved. With tractrix shaped die profile, the outside diameter of the cup is larger than the inside diameter of the draw die; nearly from the rim of the cup, the opposite is true when using a circular die profile **Danckert J. 1996.**

developed a new type of deep drawing die to increase deep drawing ratio and to decrease blankholder force by giving an angle to die and blankholder as shown in **Fig. 2**. Experimental work was carried out by drawing low carbon steel into cylindrical cup. Five different angles (0, 2.5, 5, 10, and 15)$^{\circ}$ are used in the study. It was found that an increase in the angle of the die and blankholder will increase the deep drawing ratio. Also they found that blankholder force is decreased with increase in angle for constant value of drawing ratio, as angle is set over the die and blankholder **V. Savas, O. Secgin 2006.**

THEORETICAL PART

The following equations are used to find the position of thinning and thickening during the operation [13].

The equilibrium equation

$$\rho(d\sigma_\rho / d_\rho) + \sigma_\rho = \sigma_\theta \qquad (1)$$

The flow stress equation

$$\sigma_\rho - \sigma_\theta = \sigma_y \qquad (2)$$

where

ρ, instantaneous radius of blank

σ_ρ, radial stress.

σ_θ, circumferential stress or hoop stress

σ_y, current flow stress

By equating eq. 1 and eq. 2

$$d\sigma_\rho = \sigma_y\ (d\,\rho/\rho), \text{ and } \sigma_y \ln (R/\rho) = \sigma_\rho \qquad (3)$$

Substituting eq.3 in eq.2

$$\sigma_y \ln (R/_\rho) - \sigma_y = \sigma_\theta$$

$$\sigma_y[\ln (R/_\rho) - 1] = \sigma_\theta \qquad (4)$$

where

R, radius of blank

The relationship between stress-strain is given by [14]

$$\sigma_\rho - \sigma_z / \sigma_\theta - \sigma_z = d\,\epsilon_\rho - d\,\epsilon_z / d\,\epsilon_\theta - d\,\epsilon_z \qquad (5)$$

where

σ_z, stress in direction of thickness

Under plane stress condition $\sigma_z = 0$

Then

$б_\rho/б_\theta = Є_\rho - Є_z / Є_\theta - Є_z$ (6)

where

$Є_\rho$, $Є_z$, $Є_\theta$, are the strains in direction of radial, thickness, circumferential of blank respectively

Under assumption of constant volume

$Є_\rho + Є_z + Є_\theta = 0, Є_\rho = - Є_z - Є_\theta$ (7)

$d Є_z = dt / t$; $d Є_\theta = d\rho / \rho$; $d Є_z + d Є_\theta = - d Є_\rho$

Then

$dt / t + d\rho / \rho = - d Є_\rho$ (8a)

$Є_z + Є_\theta = Є_\rho$ (8b)

Substitution equations (3, 4, and 8b) in equation (6) obtained

$б_y \ln (R/_\rho) /б_y[\ln (R/_\rho) -1] = Є_\theta - 2 Є_z / Є_\theta - Є_z$

$Є_\theta = Є_z (2 - \ln R/\rho)$ (9a)

Substitution equations (8a) in equation (6)

$[(б_\theta + б_\rho) / (б_\rho - 2б_\theta)] . d\rho / \rho = dt / t$ (9b)

$Є_z = [(1 - 2 \ln R/\rho) / (2 - \ln R/\rho)] Є_\theta$ (10)

From equation 10

If $\ln R/\rho = 0.5$, the $Є_z = 0$, that means the thickness of wall is free from thickening and thinning effects (no change in thickness occurs).

To determination the value of ρ which separates between thickening and thinning in the flange region $\ln R/\rho = 1/2 \rightarrow R/\rho = e^{0.5}$

Then

$\rho = 0.6R$ (11)

When $\ln R/\rho > 0.5$, the sign of $€_\theta$ will be opposite of sign $Є_z$.

The value of $Є_z$ equal to the value of $€_\theta$ with opposite sign when $\ln R/\rho = 1$

$t = t_o (R/\rho)^{0.5}$, this equation used to estimate maximum thickening[14].

3. EXPERIMENTAL WORK

In order to investigate the variations in the wall thicknesses of circular cup, several experiments were carried out through gradually increasing the BHF, and the spring employed for controlling the BHF have a holding force with different diameters of blanks are used for shaping flat sheets into cup-shaped articles with failure or up to excessive localized thinning. The holding force is an important factor in a drawing operation. As a rough approximation, the holding pressure can be set at a value = $0.015б_y$ of the sheet metal, this value then multiplied by that portion of the starting area of the blank that is to be held by the blank holder **Mickel P. Groover 1999**. The value of holding force experimentally is equal to 1/3 of drawing force whereas the BHG have a space equal to blank thickness and have space equal twice blank thickness, All the deep drawing operations were carried out in one step under a fixed gap (BHG), and varied force (BHF) .
The practical blank holder force changes with the variation of the punch stroke. BHF is small at the beginning of drawing process, which is good for the flow of metal towards the die cavity. The tangential compressive stress increases with the increase of punch stroke.

The wrinkling phenomenon will occur when the tangential compressive stress exceeds the anti-destabilization ability of the metal, which increases the BHF.
Instron machine type-WDW/200E (as press) is used to perform the experimental work.
Punch and die with diameters 43mm, 44 mm respectively are used to draw low carbon steel sheet (1008-AISI) with a thickness of 0.5 mm to draw a (cylindrical cups) from blanks with different reductions 0.5,0.55, 0.6, 0.65, and 0.7. The punch and die have the profile radius 4mm. The value of clearance between punch and die, C = 1.1* thickness of sheet .
Blanking operations were carried out to obtained the blanks with diameters 61.5, 66 , 71.5, 78, 86 mm respectively.
Circular cup drawing tests were performed with the BHG and BHF to investigate there effects on cup drawing for a given tooling geometry. **Fig. 3a and Fig. 4a** are shown the construction of the tool set of deep drawing with BHF and BHG respectively.

This study is concentrated on the effects of BHG = 0.5, 1 mm then compare with BHF on the circular deep drawing.
Fig. 3b, Fig. 4b, and Fig. 4c are shown the tests by using BHG = 0.5 mm, BHF, and BHG = 1mm respectively.
For experiment, tests occur at BHG = 0.5 mm also at BHF as shown in the **Fig. 3b, and Fig. 4b** respectively.Test occurs when used BHG = 1 resulting from wrinkling as shown in the figure 4c. A constant punch velocity of 10 mm/min employed for all tests reported in this paper. After completion of the drawing operation, thickness distribution and effect of reduction on the drawn cup were investigated.

4. EXPERIMENTAL RESULT

4.1. The effect of blank holders on thickness distribution

When using the holding force (blank holder), the friction between the sheet metal and the surface of the blank holder and the die plays an important role on the blank causing additional radial stress, $б_ρ$. The deformation in the flange region, the portion of blank between the blank holder and draw die shoulder is homogeneous through the thickness only at o.6R because of a radial drawing stress and a hoop compressive stress are equals in this region. When the material move from the flange region over the round die profile point A **Fig. 1**, it is bend instantaneously causing a non-homogeneous strain distribution through the thickness. Between A and B the material is generally drawn towards the punch. When the material reaches point B it is instantaneously unbend, also causing non-homogeneous deformation through the thickness.
One primary function of the blankholder is to prevent wrinkling of the flange while the cup is being drawn.

The blank holder gap has only a small effect on the maximum punch force as the blank holder gap equal to the thickness of sheet metal. The load of BHG decreases with the increase of punch stroke, which is good for avoiding breakage . Therefore any increases in the gap, the maximum blank holder force may change slightly but wrinkling can be occurred by increasing of hoop stress on cup flanges. That means the BHG has small effect on punch load and it has great effect on wrinkling, thinning, and fracture for every stage of deep drawing, these parameters increase with increases the BHG, whereas the BHF has equal effect for every stage of deep due to the decrease of the contact area between the flat surface of die and the ring of blank holder gap resulting from the flow of metal toward the die cavity during operation. In the BHG the force changes with variation of the punch stroke, it is small at the beginning of drawing process and decreases with the increases punch stroke. The maximum radial stress, $б_{ρmax}$ occurs when the cylinder drawn shape to be successfully achieved near the base of the cup. The thickness of blank must be large enough to withstand front the attack of, $б_{ρ\ max}$ if it is not withstand then the thinning of the cylinder wall occurs, mostly near the base of the cup and it is sometimes lead to the separate the base from the surrounding cylindrical wall. Thinning of thickness may not always cause tearing or failure problems during deep drawing operations.

The thickness distributions of the drawn cups are shown in **Fig. 5, 6, and 7**. Generally, there is no change in thickness distributions utill distance 14 mm from the center of the cup. After this distance, thinning occurs at 15 mm (near the base of cup) for BHf whereas at 20 mm for BHG due to BHF that prevents the metal flow especially at the initial stage of deep drawing causig high stress. After this point the BHF has equal effect for every stage of deep due to the decrease of the contact area between the flat surface of die and the ring of blank holder gap resulting from the flow of metal toward the die cavity during operation.. In the BHG the force changes with variation of the punch stroke, it is small at the beginning of drawing process and decreases with the increases punch stroke.

At BHG = 0.5 will help to metal flow at the different stages of the drawing operation. On the other hand, the large value of BHG causes excessive wrinkling which makes the metal flow difficult. The cup wall thickness slightly different in the other deform regions. Generally, the wall thickness becomes the thinnest for specimens closed to the part radius zone near the base of cup. In this region the radial stress have maximum value, the metal cannot withstand front the attack of stress, especially when thin sheet metals are used . The flange is compressed by the squeezing action of the blank perimeter a smaller circumference as it drawn toward the die opening. Because of this compression, the sheet metal near the outer edge of the blank becomes thicker,

The relationship between the reduction and thinning are shown in the **Fig. 8, 9, and 10**. There is significant change in the value of thinning for different blank diameter, the tendency for thinning is reduced as the reduction ratio of blank decreases.

The relationship between the load and travel punch during operation shown in the Fig. 11.

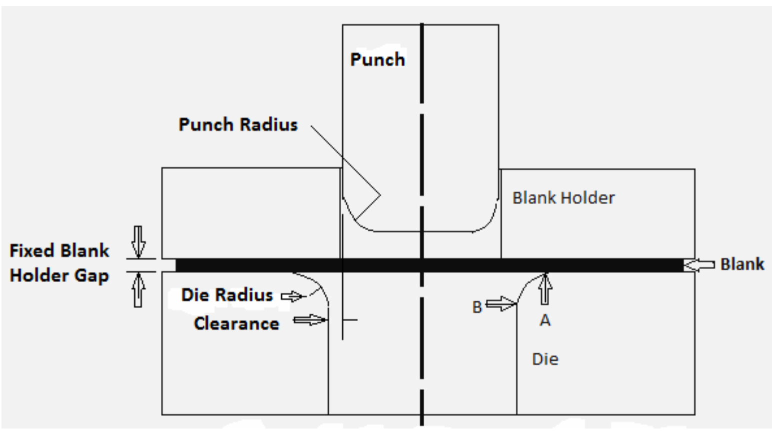

Fig. 1. Sketch of die for deep drawing operation,With fixed blankholder gap

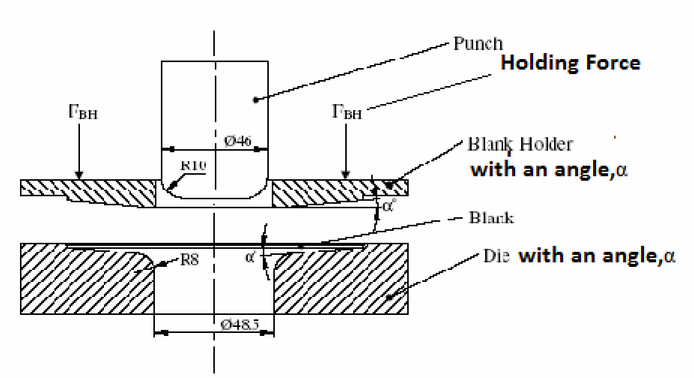

Fig. 2. Deep drawing die[11],with an angle to die and blank holder

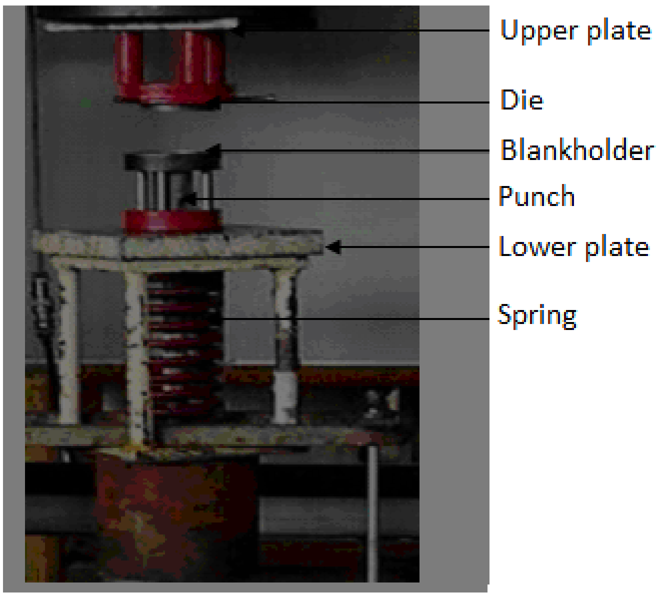

Fig. 3a. The tool set of drawing with BHF

Fig. 3b. Drawn cups obtained from tool set of drawing with BHF

Fig. 4a. The tool set of drawing with BHG

Fig. 4b. Drawn cups obtained from tool set of drawing with BHG = 0.5 mm

Fig. 4c. Drawn cups obtained from tool set of drawing with BHG = 1 mm

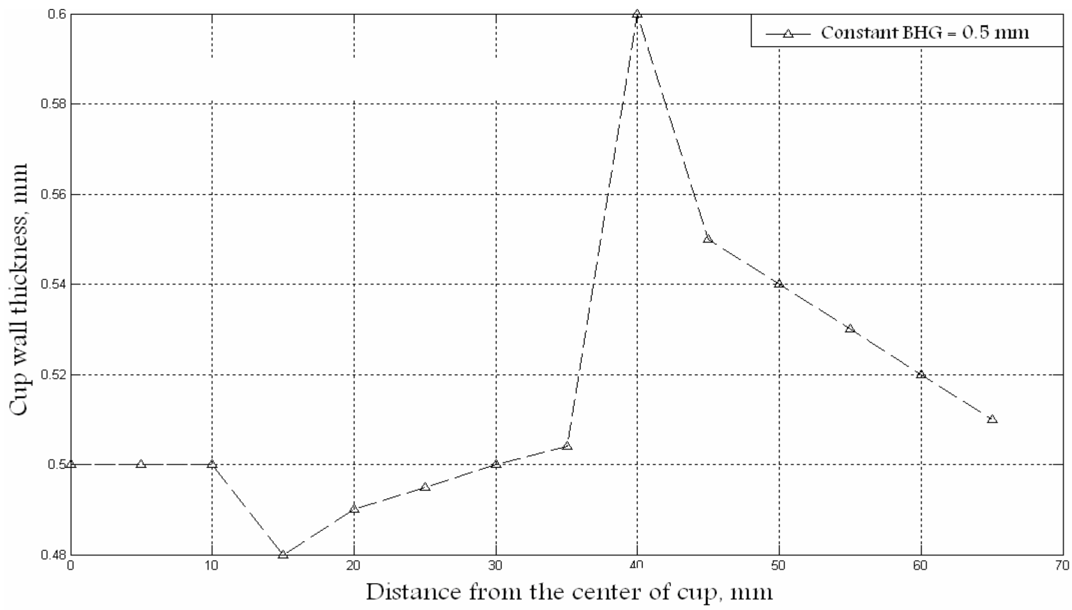

Fig. 5. Thickness distribution of cup wall

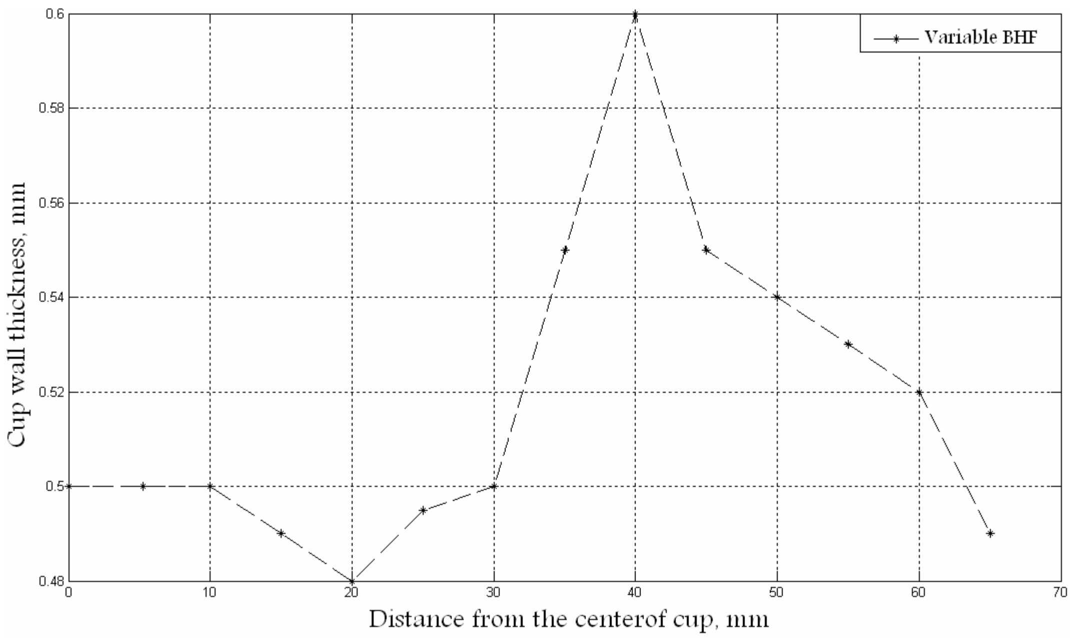

Fig. 6. Thickness distribution of cup

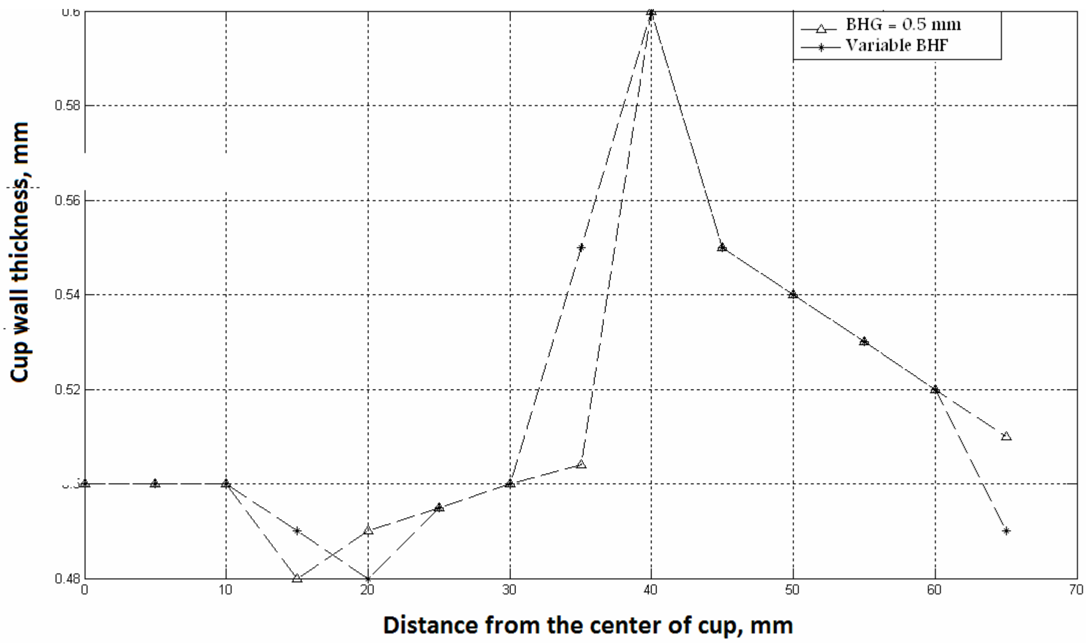

Fig. 7. Thickness distribution of cup wall

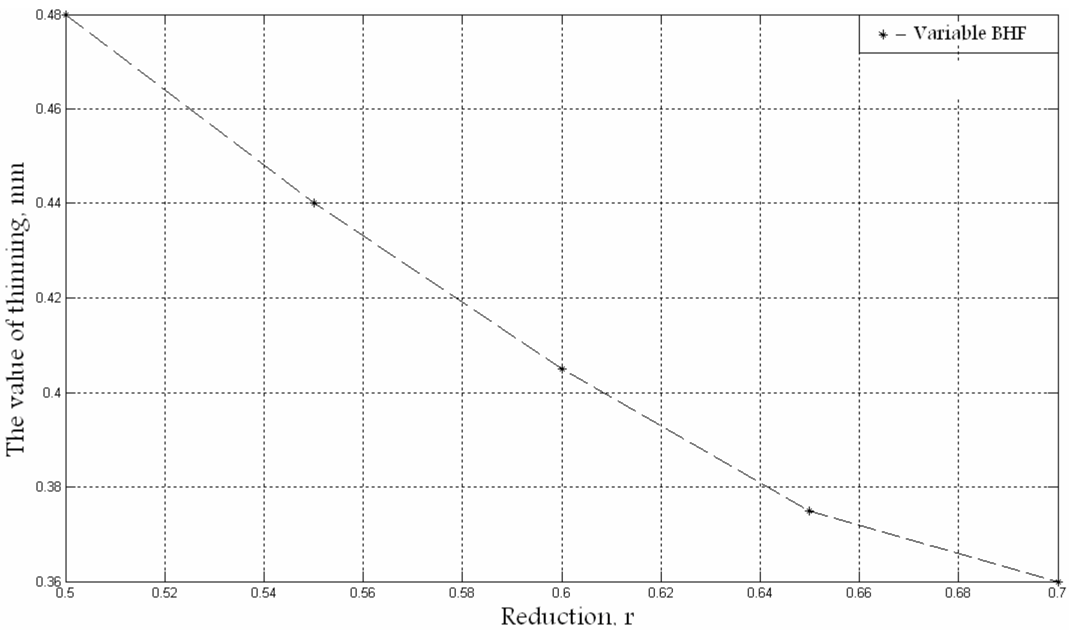

Fig. 8. The value of thinning with different reductions

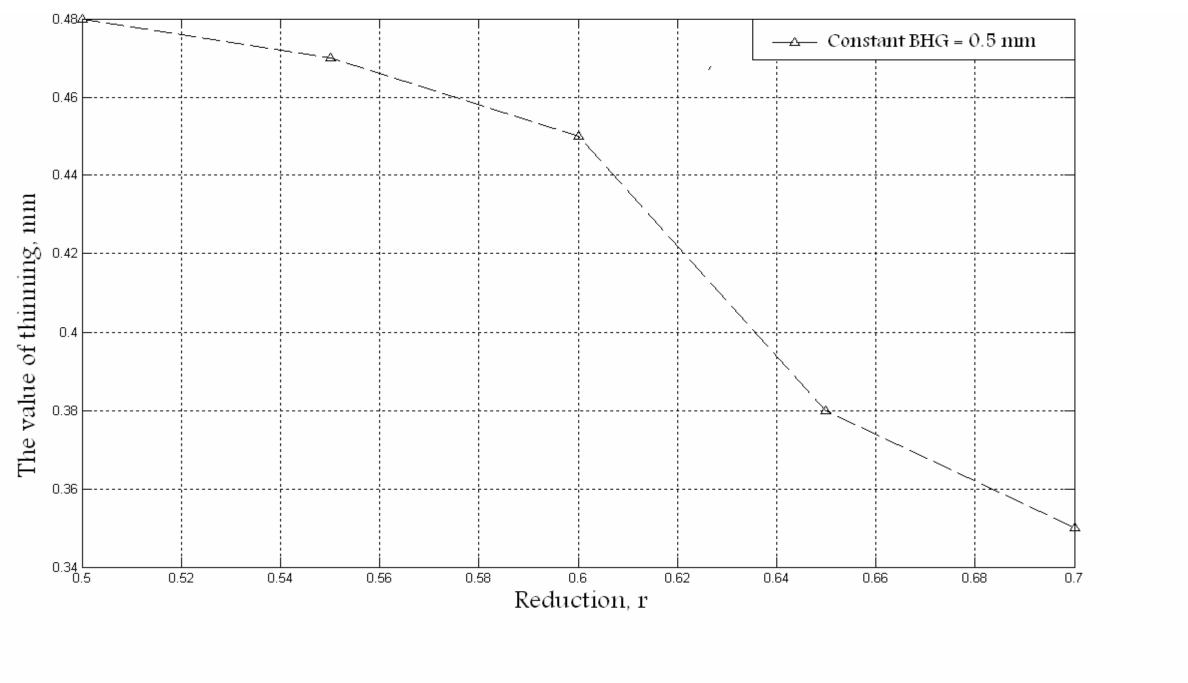

Fig. 9. The value of thinning with different reductions

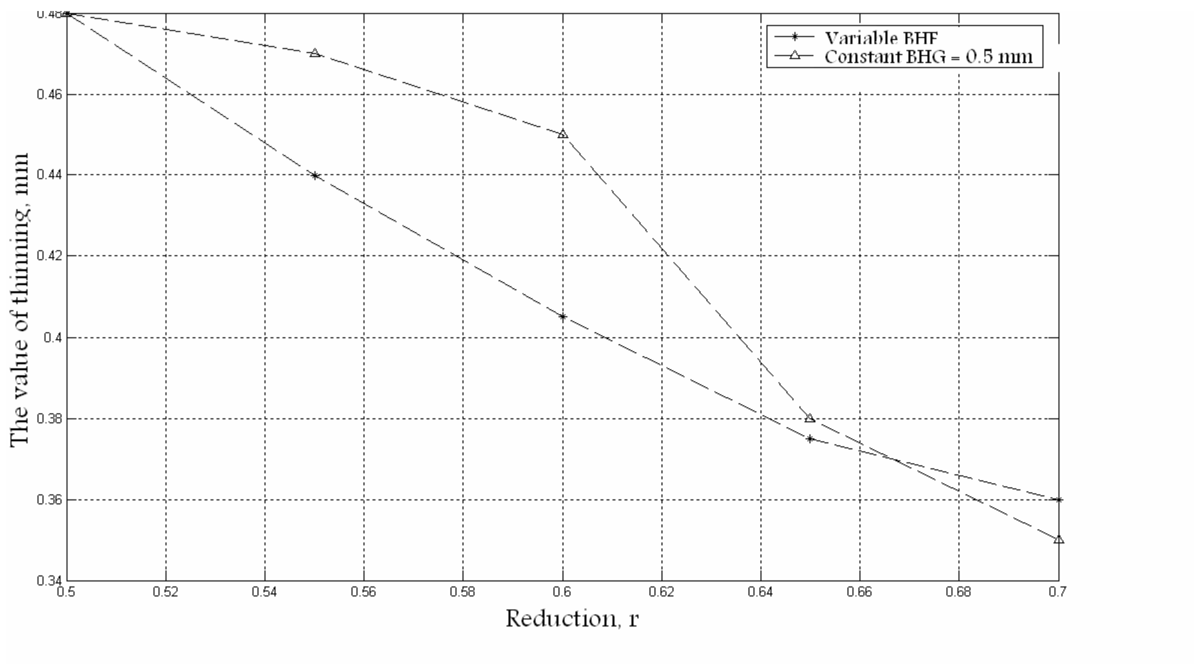

Fig. 10. The value of thinning with different reductions

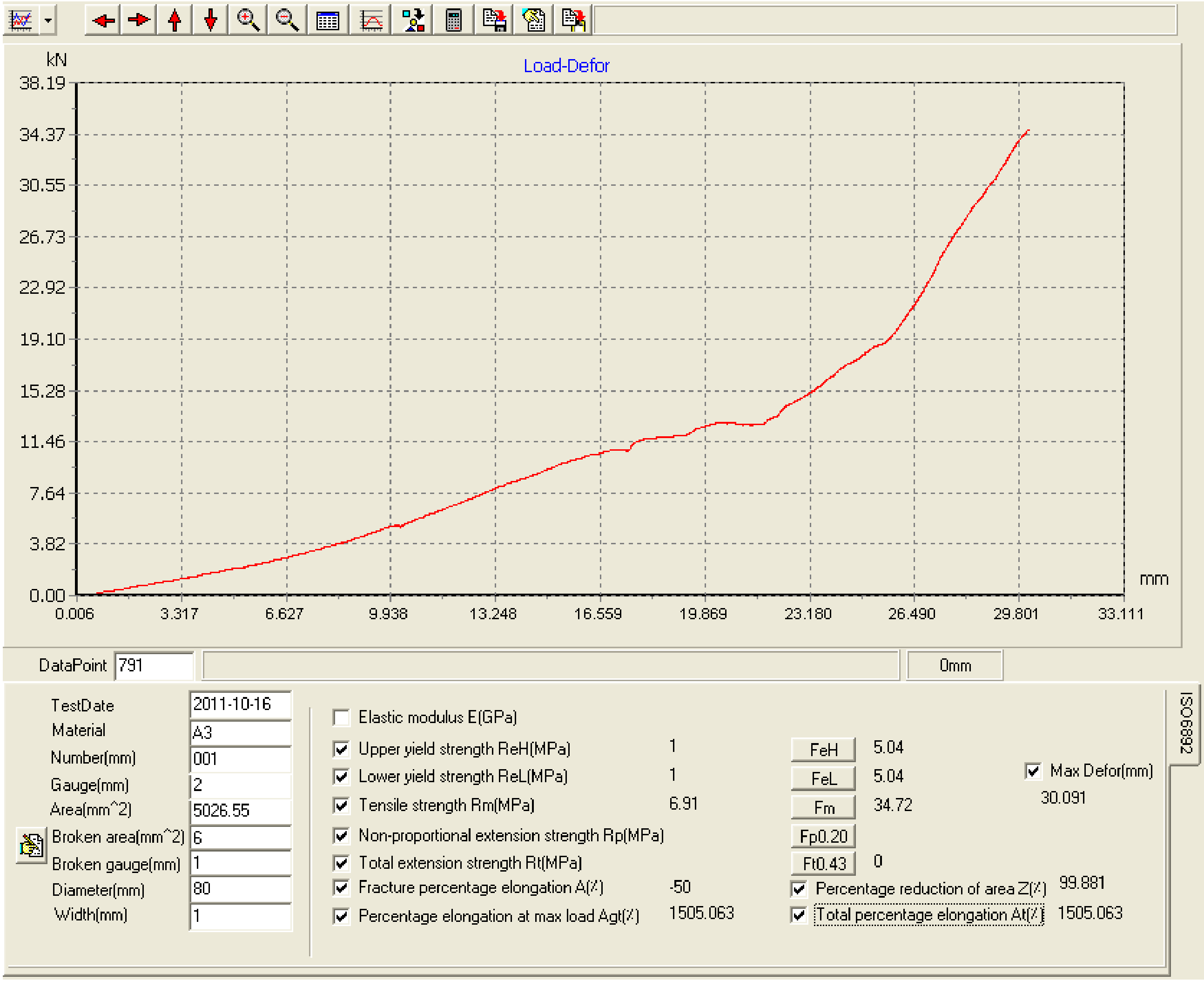

Fig. 11. The relationship between the load and punch travel during operation

CONCLUSIONS

In this paper, circular cups of a steel sheet have been formed experimentally. The effects of BHG and BHF on the thickness distributions have been investigated.

- In spit of the increasing of the BHG allows more material to be drawn into the die cavity. But it is impossible to use too large BHG because of excessive wrinkling and buckling at the straight sides which cause tearing.
- It was found that, under the above-mentioned conditions, the best drawing test when the BHG is equal to blank thickness. If the BHG is larger than 0.5 mm, the cup will fracture resulting from wrinkling and the BHG is smaller 0.5 mm, that is impossible.
- The experimental results proved that the theoretical calculation always is identity.

6. REFERENCES

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