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The Effect of Die Types on Yield for Drawn Copper Sheet in a Pneumatic Forming

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Abstract

Pneumatic forming of nonferrous alloys is widely used to produce components for many traditional and advanced applications. The plastic behaviours of high purity copper sheet were investigated under pneumatic forming using open and closed dies. Experimental yield loci were determined based on the strain energy theory for open and closed dies. It has been found that the yield loci in open die expanded more than that in close die. The formability was improved due to reduction in friction coefficient. The plane strain forming and the strain distribution remain mainly uniform throughout the drawing sheet. The formed copper sheets were not thinned at the centre of the doom.

Keywords: pneumatic forming.

تأثير نوع القالب على الخضوع لصفائح النحاس بطريقة التشكيل الهوائي

الخلاصه

التشكيل الهوائي للسبائك اللاحديدية يستخدم بصورة واسعة لإنتاج الأجزاء للتطبيقات التقليدية والمتقدمة. لقد تم دراسة التشكيل اللدن لصفائح النحاس ذات النقاوة العالية تحت تأثير التشكيل الهوائي بأستخدام القوالب المفتوحة والمغلقة. ولقد تم تحديد منحنيات الخضوع بصورة عملية بالأعتماد على نظرية طاقة الأنفعال. أوضحت الدراسة بأن منحنيات الخضوع للقوالب المفتوحة تتمدد بصورة أكبر من التشكيل بالقوالب المغلقة. بقيت مستويات الأنفعال وتوزيع الأنفعالات بصورة منتظمة للصفائح المشكلة. ولم يحصل أي تنحيف في مركز الصفائح المسحوبة.

Introduction

The hydro - pneumatic forming is still to be considered as a new and advanced technique in which a straight or prebent round tube or sheet is placed in a closed die cavity or free and cross sectional shape is changed by using a hydraulic or pneumatic pressure. Pneumatic sheet forming has many distinct advantages compare to forming with solids tools atypical set of dies. It has one third of the tool cost in each half of the die and the final one third in trying time .Sine the hydroform die has only one half a die, a tooling cost reduction of 65 percentage often is possible [1].

The defect like off wrinkling or tearing were produced in deep drawing part were eliminated by a use accurate fluid pressure by control system [2,3]. It has been possible to draw a cup with a drawing ratio of 3.1 with the blank made from soft aluminium [4], where parts with a

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higher strength and a lower weight may produce unique shapes. This technique used to form stainless steel, steel, copper, aluminium and brass; the internal pressure change from 2000 bar to 10000 bar [6]. The change rate of the internal pressure is an important to the process as absolute value of the pressure. Large strain rates begin to reduce the formability when the operation becomes too rapid in deformation. In the closed die by pneumatic forming process two zones of friction characteristics are transition and expansion zones. The transition zone is the region where the materials form on the radius of die and expansion zone is the region where the material forms to the die geometry. Each zone experiences different friction characteristic during the forming operation [7].The parameter are affecting the friction coefficient are the sheet material, the die material and die surface characteristic and lubricant [8,9].

It was found by Hecker [10] that the analysis of strain-hardening materials subjected to multiaxial states of stress requires more detailed experimental information about the effects of previous plastic deformation on the yield surfaces of real materials than is presently available. To provide insight into some of these effects thin walled tubular specimens of annealed OFHC copper were subjected to biaxial stresses through the application of simultaneous axial tension and internal pressure, and the effects of the magnitude, direction, and sequence of prestraining operations on subsequent yield surfaces were determined. Thin-walled tubular specimens of OFHC copper were also loaded biaxial through the application of simultaneous axial load and internal pressure [11]. The effects of loading path and deformation history on the stress-strain and yield locus characteristics were studied at strains less than 2.0 pet The observed plastic strains for both materials depended on the loading path to a given stress point, whereas the loading path during prestraining did not affect subsequent deformation.

A concise review of different proposed phenomenological equations that describe the behaviour of sheet metals and their influence on theoretical forming limits is presented by Barlat [12]. It was also found that the geometrical features of yield surface shapes are very necessary to achieve high formability. A redeveloped model described the localized plastic flow in sheet material which it takes into account the anisotropic yield function together with isotropic work hardening.

Svensson and Metcalfe [13] developed simplified model which predicted the corners that identified in the yield locus following prior plastic straining. The model predicts the shape of the comer associated with different types of combined stress prestrain. The model is sufficient to be used to quantitatively predict the nature of the corner.

Materials and Procedures

The metal is annealed high conductivity pure copper with thickness (0.65mm) as a sheet. All samples were taken from a single lot of copper sheet. Uniaxial tests according to ASTM-E8 rectangular dog-bone shape samples were used. The samples were tested using Instron machine with 1 0 tones capacity. The tensile samples were prepared from the copper sheet metal at 00 (rolling direction, RD), 450 and 900 (transverse direction, TD) from the rolling direction of the sheet. The results reported are the average of three tests. The measurements of plastic anisotropy parameter were performed on the polished surfaces to measure the dimensions by general microscopy. The anisotropy is typically characterized by Lankford's coefficient [14] which define as:

$R = d€_w/de_t=l/R+l$ ....(1)

Where $d€_w$ and dG_t are the strains in width and thickness directions, respectively. Lankford [14] suggested the material anisotropy be represented by an average strain ratio. R, defined as:

$R = R_0 + 2R_{45} + R_{90}/4$ ....(2)

The slopes of yield loci at the points (X, 0), (0, Y) were defined by:-

$\tan O = dG_w/de_t = 1/R + 1$ ..... (3)

The biaxial compression test on adhesively bonded sheet laminate specimens used in this study was performed by [15-17]. The biaxial compression process was fulfil the equal biaxial tensile stresses (01 = 02). The deformation in biaxial compression must be under ideal conditions and the ratio between h and d was 1-1.5 to prevent buckling. To minimize barrelling and friction, an effective lubrication was used. The tests were performed on Instron machine. The dimensions of specimens were measured by micrometer with accuracy of 1 micron. Equations 1, 2 and 3 were used to obtain the yield criterion curves. The plain strain tension used in this study were achieved on a circular disc with outer diameter of 170 mm prepared on turning machine with high accuracy on model formed from the wood. The samples were drawn using two dies, the first is open die (Figure 1) and the second one is closed die (Figure 2). The shapes of drawing samples using open and closed dies are shown in Figures 3 and 4 respectively. The tests were performed at 0.3 mm/min strain rate.

Results and Discussion

The results of yielding copper sheets were obtained at different work done per unit volume at different types of stresses. These data were used to obtain the yield locus of copper sheets for both dies. Figure 5 is a typical example of yielding criteria for copper sheet drawn using the open die. It has been found from the experimental results that the shape of die plays an important role in the shape of yielding criterion. The yield loci for sheet metal of copper at different work done per unit volume at several levels have affected the shape of the yield surface (Figure 5). The change in the shape of yielding criterion is particularly noticed near the balanced region of the yield surface. It is affected on the shape of yield locus; the yield locus at low work done is elliptical shape. With increasing the work done, the yield locus takes a square shape which is due to reduce the ductility during forming.

It was found that the effect of yield has an important effect on the behaviour of drawn copper. At a low value of stress, there is a very anisotropic on the surface. On the other hand, at high values of stresses an isotropic yield surface characteristic was obtained. It was also observed a Bauschinger effect This behaviour reflects the formation of both isotropic and kinematic hardening mechanisms. The microstructure was found to be consisted of sharpened cell walls with misorientation of approximately a few degrees between the individual cells.

Conclusions

The yield surface at the constant work done for the sheet drawing indicates the following

1- The shapes of initial yield surface have been elliptical and changed to shapes of square as results of work hardening.

2- The formability of copper sheets using the open die is better than the closed die.

3- The ability of shaping the sheets in open die to produce dome is higher than the closed die at the same bearing pressure.

4- The sheet copper formed using closed die losses the ductility at lower depth of forming.

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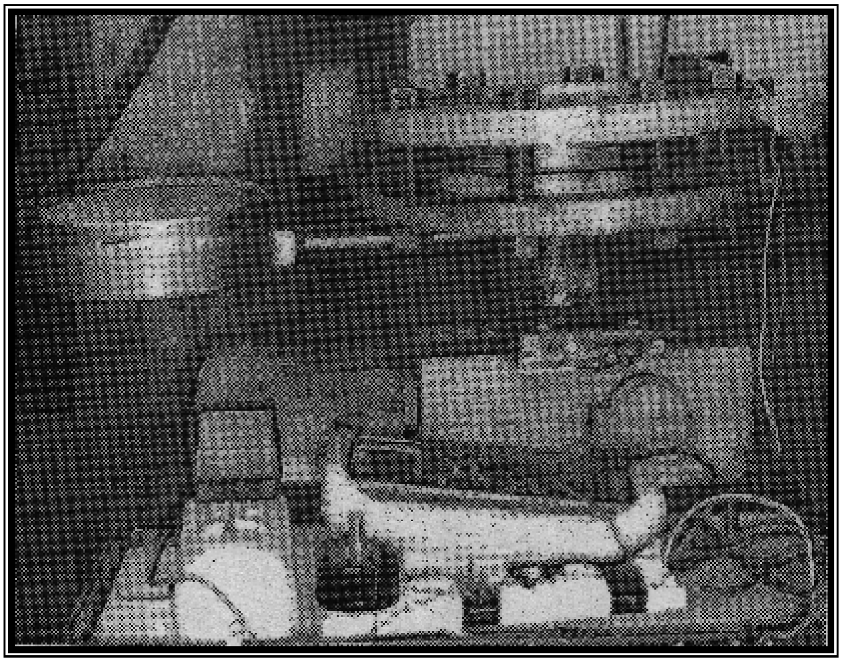

Figure (1) The pneumatic open die drawing.

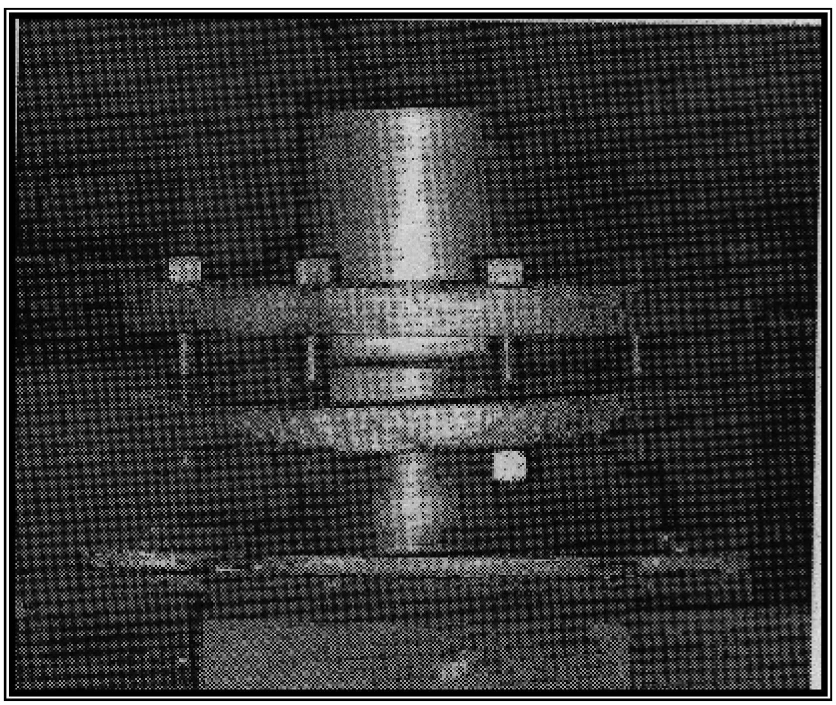

Figure (2) The pneumatic closed die drawing.

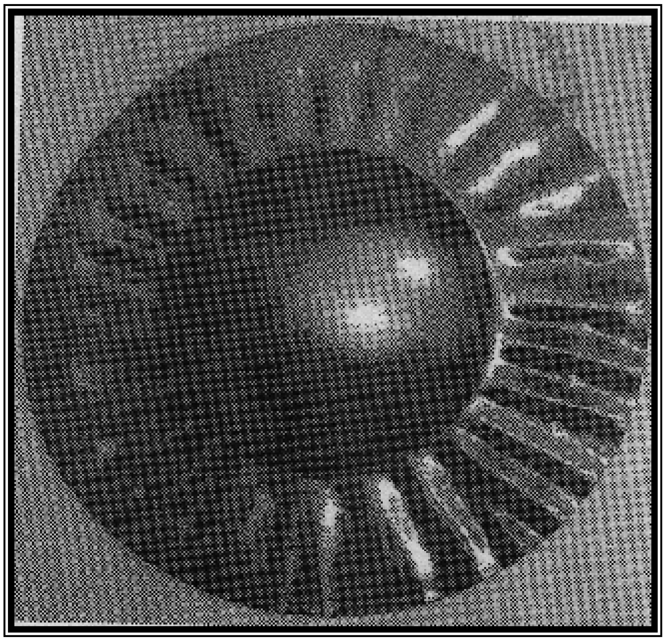

Figure (3) : The blank drawing in open die , dome height (23.2 mm) and diameter of sheet drawing (86 mm) , 35 bar.

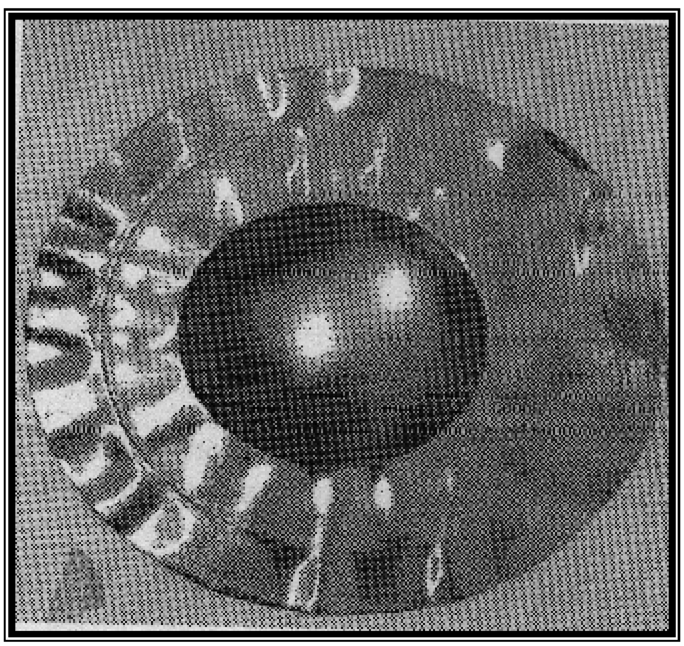

Figure (4) : The blank drawing in closed die , dome height (19.5 mm) and diameter of sheet drawing (83 mm) , 35 bar.

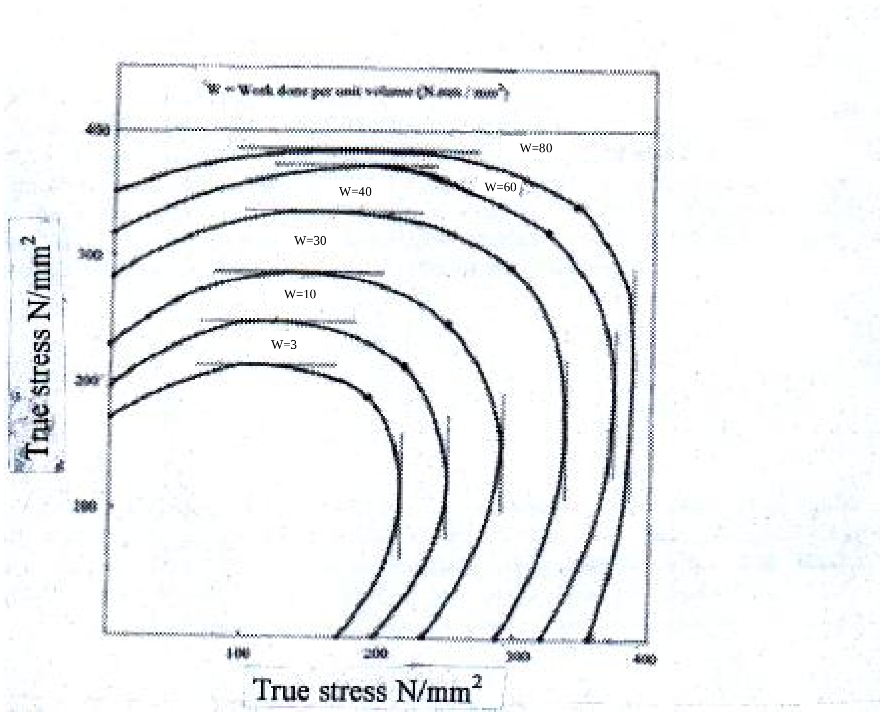

Figure (5) : Experimental yield criteria for Cu sheet drwned in open die (90^o) at different work down per unit volume, W (Nmm/mm^3)