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Hydroforming of High Purity Copper Sheet To Produce Different Shapes

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Abstract

The present research is focused on experimental results and theoretical analysis of sheet hydronning of high purity copper with circular and square shapes under the biaxial stresses. It has been found that the displacement in the circular shape specimens is more than of the square shape specimens at the same area of deformation. However, at the same time. The plastic deformation equivalent at the specimens for the circular shape is more than of the square shape specimens at the same strain equivalent. The thinning of the sheets at the pole for the circular shape specimens is less than that of the square shape specimens. This will lead to improve the performance of the circular shape product.

Keywords: Hydroforming; Copper sheet; biaxial stresses; circular shape; square shape.

التشكيل الهيدروليكي لصفائح النحاس عالي النقاوة لانتاج اشكال مختلفة

الخلاصة

يركز البحث الحالي على النتائج العملية والتحليل النظري للتشكيل الهيدروليكي لصفائح النحاس عالي النقاوة لانتاج اشكال ذات مقاطع دائرية ومربعة تحت تاثير الاجهادات الاحادية. لقد تم ايجاد بان الازاحة لنماذج الاشكال الدائرية اكثر مقارنة مع نماذج الاشكال المربعة تحت نفس تاثير مساحة التشكيل. لكن بنفس الوقت فان التشكيل اللدن المكافى لنماذج الاشكال الدائرية اكثر من التشكيل للنماذج المربعة عند نفس مكافى الانفعال. التنحيف للصفائح عند مركز التشكيل لنماذج الاشكال اقل من نماذج الاشكال المربعة. هذا سوف يودي الى تحسين الاداء لمنتجات الاشكال ذات الشكل الدائري.

1- Introduction

Sheet hydroforming (SHF) is considered as an important metal forming similar to that of tube hydroforming in which cups with different shapes are produced with a given die cavity using an internal pressure and axial compressive forces [1, 2].

This forming process is well accepted for manufacturing of many Ferrous and nontcrrous metals and alloys [3]. The hydroforming process Consists of a combined loading of compression forces and an internal pressure applied by a fluid media in order to obtain different domes with Different cross sections [4j. Many studied have been made to understand and determine the interaction between dependent and

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independent variables [5] to produce defect-free products as possible. In spite of there were many investigations regarding the hydroforming of tubes, there are dearth of information of hydroforming of copper cups [6.7]. There are well established that the successes of any hydroforming process heavily depended on the mechanical and physical properties of the sheet metal or alloy such as yield strength, tensile strength, hardness, ductility, strain hardening value, plastic anisotropy. Crystal structure and surface finish [8,9].

In the present years, the sheet hydroforming or pneumatic forming processes are being increasingly progressive techniques for fabrication light and heavy structures with high aspect ratios. These structural parts were used extensively in automotive, household and aerospace industries [10]. The advantages of these processes compared with other forming technologies are cost effectiveness; saving materials, high strength products, weight reduction, good accuracy, high deformation, high hardness, reduce the force at the beginning of the stroke prediction tools, improve quality, reduce prototype cost and reduce the level of operation noise [11,12]. Sheet hydroforming processes have been investigated by various researchers [13, 14]. These techniques have been proven to be cITicient and economical to produce many products such as tubular sections [15], elbows [16], spherical vessels [17] and double-blank hydroforming [18].

The forming operation in the dies requires two stages [19]. The first stage is free forming operation of the sheet bulged: in this stage the sheet deforms freely in the dies cavity until it contacts the dies surfaces. The free bulging leads to material to be .deformed uniformly with reduce the tearing produces highly from the localized deformation. The sheet leans against the dies walls and the flow of sheet is restricted due to the friction effect between sheet/dies surfaces. The second stage involves calibrating the sheet against the die cavitv to obtain the final desired shape. The amount of pressure needed in the sheet hydroforming processes are dependent on the sheet material properties, thickness of the sheet, part complexity, dies complexity, shape corner radius, dies sliape. Dies angle, roughness of the dies and dimensions of the part produced [20].

2- Materials and experimental procedures

The cups hydroforming experiments have been performed on a high purity copper sheet (99.99%) of 0.65 mm thickness and the mechanical properties are reported in-Table 1. The sheets used in hydrofrming are in the annealed conditions. All the samples were taken from a single lot of copper. Circular and square sheets with diameter or width of 170 mm were cut using a lathe machine; these were achieved by using a wood model. Experiments were carried out on a build up laboratory hydroforming machine which was developed for this study. Fig. 1 shows the details of the experimental setup used for studying hydroforming process. The apparatus was fitted with two ports; one for measuring the internal pressure applied and the second one for measuring the displacement. The internal fluid pressures at the mean strain rates were applied manually by the handle of oil pump supplying the oil from the tank. The circular and square shapes of the dies and cups formed are shown in Figs. 2 and 3 respectively. The thinning evaluation of the deformed sheets were determined by using a dial gauge with an accuracy of 0.01 mm by measuring the variation of thickness. The measurements obtained for estimating the sheet thinning were along the die diagonals of the samples.

3- Experimental and theoretical results

In hydroforming studies it is very necessary first to determine the relationship between the displacement (h) and internal pressure applied (P) for both domes using the circular and square dies (Table 2). It can be seen clearly from Table 2 that the displacement of the circular blank is higher than the square one under all values of pressure applied.

Calculation of the flow stress was carried out. based on the measured dome height (displacement), h and the bulging pressure, P according to references [21-23]. Values of P. td. d and h have been measured for each test to determine. Ten test have been made for each shape. where is the equivalent flow stress, R is the curvature radius at the pole, td is the actual thickness of the sheet at the pole, t is the bulging diameter and h is the instantaneous height at the dome apex. The strain equivalent and actual thickness can be determined by using the following equations [24].

All the hydroforming samples under all the parameters studies for both shapes characterize with wrinkling phenomena; typical example is shown in Fig. 3. The phenomena of wrinkling are considered as a complex that is highly affected by all parameters of the copper sheet and processing variables. It can be concluded that the shape of the blank plays an important parameter. In the square blank, the amount of wrinkles is less compared with circular blank. This may be related to a high compress stresses formed in the flange zone of the circular blank; due to easily drawn of the copper sheet. The value of equivalent strain is highly dependent on the value of actual thickness of the pole. td; it is lower in the circular shape which means a higher equivalent strain (Table 3). This is resulted in a higher thinning of the circular shape as shown in Fig. 4.

Results presented in Fig. 5 between the equivalent stress and equivalent strain show that a given constant pressure, the equivalent strain and equivalent stress are higher for circular shape compared with the square shape. This is explained by returning to the equations 1 and 2. It shows from equation 1 that at a given constant pressure, the equivalent stress is a function of both R and t (t is constant for both shapes). This it means the equivalent stress is related directly to R value. Therefore, for the circular shape, the dome high. H and d are higher. This is resulted in a higher value of R and consequently a higher value of equivalent stress. The maximum depth of domes for both shapes as a function of internal pressure is shown in Fig. 6. It appears they have a similar trend, but with different quantitatixe values of depth; they related directly to different values of equivalent stress.

In both haydroforming shapes, the wall thickness is different in different areas, 'this phenomenon may be explained that during any hydroforming process the sheet will bent to take the performed shape. Bending the thin copper sheet used on the outside of the bend and thickness it on the inside. The magnitude of [he wall thinning variation is relatively increased with increasing the internal pressure. Detailed study should be carried out to reduce the wall thin inning variation. It should be noted from Pig. 4 that the wrinkling defects was found for both outer surface of forming shapes. The formation of wrinkling is related to local buckling due to instability. This phenomenon was explained in detail previously by [25]. It was explained due to the axially loaded specimen deforms so that the new geometry, from a mathematical point of view, is in a stable state of equilibrium. By continuous increase of the force, the state of equilibrium is formally maintained, but at a certain time it becomes unstable. At this critical point, even the smallest disturbance such as non-centered point of application of force, inaccuracy due to manufacturing, etc will lead to instability. This holds for a buckling of a bar as we as for the wrinkling of sheet metals. It should be mentioned that the process of sheet hydro forming, different than the conventional forming, it involves supporting the bottom of the sheet with applying the internal pressurized fluid. This will lead to produce compressivc stress through the thickness of the sheet. This finally leads to delays the onest of'tensile instabilities; it leads to reduce frictional force and finally the wrinkling.

Conclusions

1- The thinning in the semisphcrical was less than the square at the same condition of hydroforming drawing for high purity copper.

2- The dome height in the semisphcrical was higher than the square specimens at the same areas of hydroforming drawing sue to low equivalents flow stress.

3- The stresses in the hydroforming for semispherical is higher than the square specimens at the same strain.

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Table 1 Mechanical properties of high purity copper studied

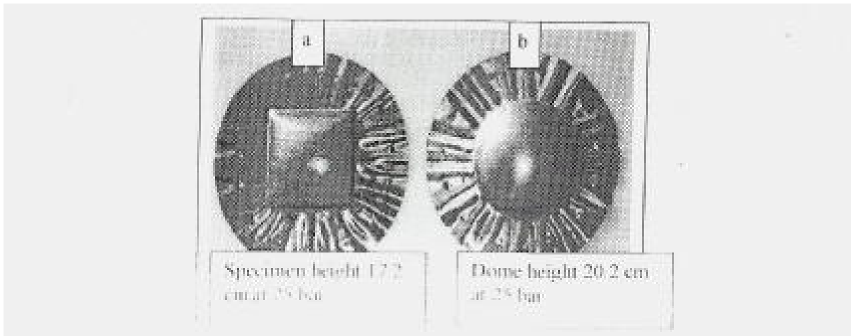
Displacement, h, mm	Internal pressure, bar , Circular sheet	Internal pressure, bar , square sheet
0	0	0
2	4.3	2.8
5	7	5
7.5	9	7
10	11.5	9.4
12	14	11.5
15	16.5	12.9
17.5	18.1	14
20	19	15
22.5	20	16
25	21	17

Table 2 The relationship between the displacement and internal pressure

Hardness	40 HV
Yield strength	70 MPa
Tensile strength	200 MPa
Young's Modulus	1 l 5 GPa

Table 3 the relationship between the equivalent strain and equivalent stress

Equivalent strain	Equivalent stress, Circular specimen	Equivalent stress, square specimen
0	0	0
0.025	55	43
0.05	60	50
0.075	69	58
0.08	75	57
0.125	80	63
0.17	90	75
0.22	110	80
0.28	120	90
0.33	130	100
0.38	150	110



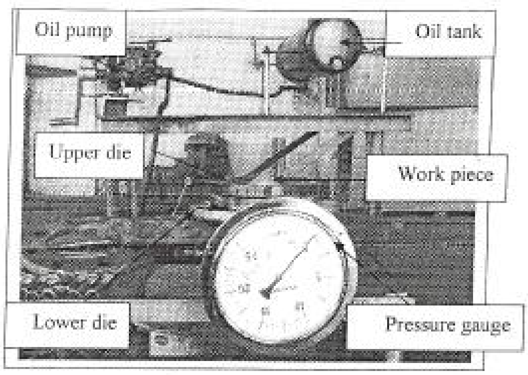


Fig 1 the equipment of hydroforming sheets metals

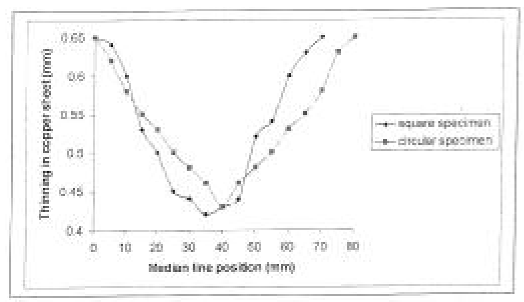


Fig 4 Thinning of sheets along the diameters lines

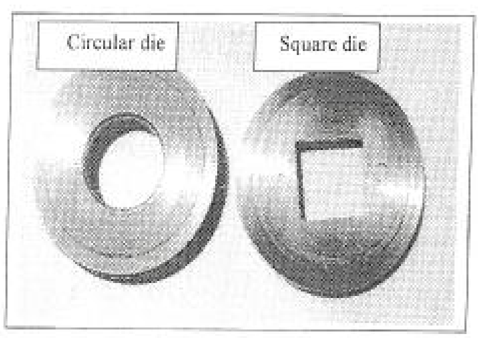


Figure 2 (a) Square & (b) circular dies in the hydroforming drawing process.

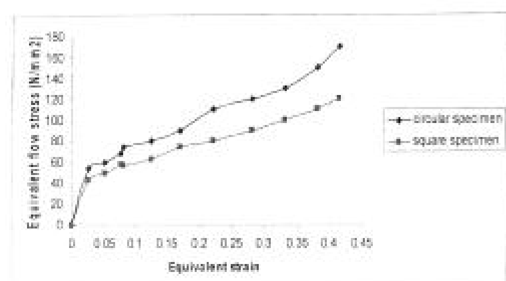


Fig 5 The relation between the equivalent stress and strain in hydrofor of copper sheets

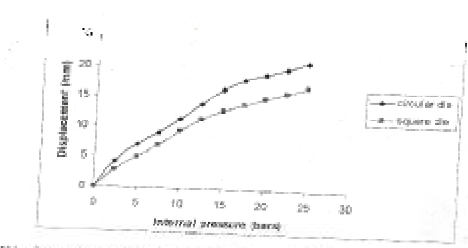


Fig 6 Displacement versus internal pressure in hydroforming of copper sheets

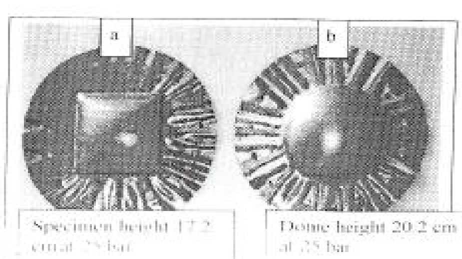


Figure 3 (a) Square & (b) circular specimens under biaxial stress testing in the hydroforming drawing process