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Effect of Punch Profile Radius on the Deep Drawing of Flat Ended Cylindrical Brass Cups

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Abstract— Deep drawing is a secondary metal forming process which is widely used in automobile and air craft industries for manufacturing the body and spare parts. In this paper, the effect of the punch profile radius on the autographic records, thickness strain distribution, maximum amount of thinning, maximum drawing force and the total consumed work in drawing of flat ended cylindrical 70/30 brass cups is investigated. The obtained results are presented and discussed.

Index Terms— Effect, Punch profile radius, Thickness strain distributions, Maximum amount of thinning, Maximum drawing force, Total consumed work, Deep drawing of 70/30 brass, Flat ended cylindrical cups. .

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1 INTRODUCTION

DEEP drawing is the most widely used process among sheet metal manufacturing processes. It is used for manufacturing many engineering and industrial parts especially in the aircraft and automobile industries. As early as 1939 when Swift, published his first experimental work on cup-drawing seems to be that in 1939, [1, 2], the researchers in the manufacturing field got engaged in investigating the process under cold condition and a large number of publications were reported in the open literature regarding the mechanism of deformation, the parameters affecting the process e.g. drawing ratio, blank holding down pressure, limiting drawing ratio, radial clearance between punch and die, c, normally it is defined with respect to the original sheet thickness, c/t and referred to as radial clearance percentage, c/t %.aiming at reducing the defects encountered in the produced cups and to render the process cost effective, [3-27].
Recently, the area of research in this field has extended and covered different aspects of the process, e.g. warm and hot deep drawing where considerable effort is being devoted to them due to their effectiveness in enhancing formability, [5–7], surface texture and grain size, [16, 20], friction and lubrication, [20-26], simulation using finite elements, FE, 24-26] and the control of the distribution of the holding down force. The control of strain paths by means of variable blank holder force is used by many authors to enable successful drawing of parts with complex geometries, which could not have been drawn using a constant blank holder pressure. Brief description of these publication is summarized by the authors, [27].

LIMITING DRAWING RATIO OF CYLINDRICAL DRAWING CUPS, LDR

The limiting drawing ratio, LDR, in cup drawing is a very important parameter. It usually involves quite a number of process variables such as yield strength, strain hardening exponent, strain rate sensitivity, normal anisotropy value, friction coefficient, die profile radius and half the die opening. A practically applicable equation for estimating the LDR in the cylindrical cup drawing with a flat enned punch has been derived using an integral technique based on the load maximum principle for localization of plastic flow.
The obtained results have shown that LDR increases with the increase of strain rate sensitivity. Furthermore, it was found that there is an interaction between the process parameters and the LDR which made better understand and control the cup drawing behavior for optimum press drawability.

2 MATERIALS, EQUIPMENT AND EXPERIMENTAL PROCEDURES

2.1 Materials

The specimens were circular discs of 180 mm diameter and 0.387 thickness made from 70/30 brass of the mechanical behavior shown in Fig.1.

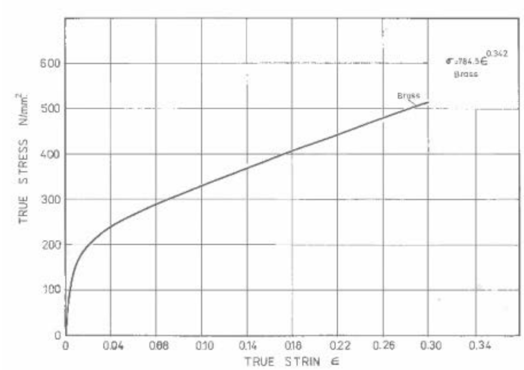

Fig. 1. True stress-true strain of the work piece material, brass

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2.2 Equipment and Experimental procedures

The deep drawing tests were carried out using the deep drawing die shown in Fig.2 which was designed and manufactured for this purpose. It consists of the following main parts: the upper and lower platens which are concentric and held in line together, the sleeves the blank and die holders were all made of galvanized steel.

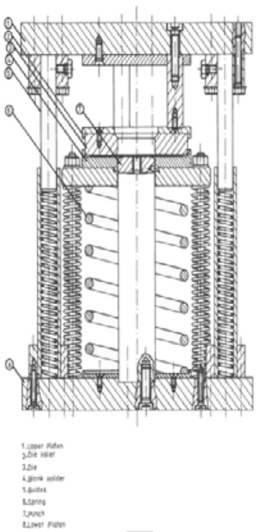

Fig. 2. Schematic drawing of the deep drawing die

The main deep drawing die and all the other punches and dies which were used for investigating the different parameters were all made of the same material, X12M of the chemical composition shown in Table 1. They were all heat treated according to the treatment cycle provided by the suppliers to achieve a hardness of RC58.

TABLE 1
CHEMICAL COMPOSITION OF X12M

Element	Wt. %
C%	1.70%
Mn%	0.35
Si%	0.4
Cr%	0.12
V%	0.3
Fe%	Bal.

Five punches and five dies with different diameters and different profile radii were machined and ground under the same cutting conditions. Their diameters were measured using the Tool Makers travelling microscope and their profile radii were determined using the shadow graph at a magnification X20. The values of the punch and die profile radii are shown in Tables 2 and 3 respectively.

Five punches and five dies with different diameters and different profile radii were machined and ground under the same cutting conditions. Their diameters were measured using the Tool Makers travelling microscope and their profile radii were determined using the shadow graph at a magnification X20. The values of the radial clearance percentages for different combined punches and dies were published by the author in []. The optimum value of the radial clearance percentage, 130 %, was used in this work and the best effective lubricant as reported in []

TABLE 2
VALUES OF PUNCH PROFILE RADII

Symbol	Punch profile radius (mm)	Rpn/pr
rp1	2	3.34
rp2	5	8.34
rp3	10	16.67
rp4	15	20
rp5	20	33.34

TABLE 3
VALUES OF DIE PROFILE RADII

Symbol	Die profile radius (mm)	Rdn/dr
rd1	2	4.77
rd2	4	9.53
rd3	6	14.3
rd4	10	23.84
rd5	15	35.75

3 MATERIALS, EQUIPMENT AND EXPERIMENTAL PROCEDURES

In this section, the effect of punch profile radius on the autographic records of combination with the five manufactured dies, on the thickness strain distribution, the maximum drawing force and total consumed work are presented and discussed.

3.1 Effect of Punch Profile Radius on the Autographic Records

Figs 3 and 4 show the autographic records for the combinations of P1 and P4 with the five dies five dies: D1, D2, D3, D4 and D5 respectively. It can be seen from these two figures that the general trend in both of them is similar except in the maximum drawing force and the value of the punch travel for the successfully drawn cups despite that the curves are sharper in case of Fig.3 i.e. less distance in the punch travel and of slightly lower values of the maximum drawing force knowing that the punch profile radius in Fig.3 is 2 mm and in Fig.4 is 15 mm. This is attributed to the severity of the work hardening in the small value of the punch profile radius as compared to the case in Fig.4, where the punch profile radius is much larger. Furthermore, it can be observed that the difference in the maximum force in case of P4 is more pronounced than in case of P1 unlike the expectations as it is expected that the maximum force will be sharper and higher in P1 as the strain hardening is higher for a sharper bend. This indicates that the maximum drawing force is more affected by the die profile radius as compared to the punch profile radius.

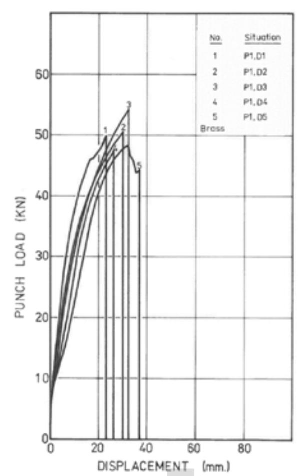

Fig. 3. Autographic records Punch 1 with the five dies

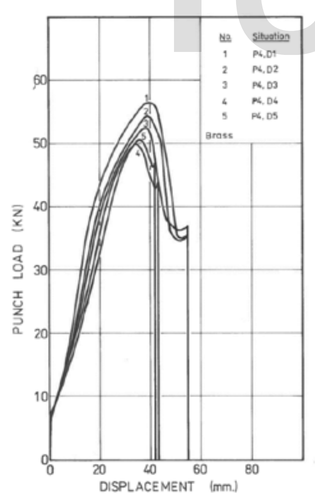

Fig. 4. Autographic record of punch 4 with the five dies

3.3 Effect of punch profile radius on the thickness strain distribution

For all values of punch profile radius values and combinations with different dies, the general trend is almost the same except with different values of. the maximum amount of thinning as indicated in Figs. 5 and 6. It can be seen from these figures that the maximum amount of is about 8 % for the combination of P2, P3 and P5 with D1 and only 7 % maximum thinning for combination of P4 with D1. It is worth mentioning in this respect that these regions are the weakest zones in the cup which will cause necking and will lead to fracture. This is explicitly illustrated in Fig.7.

Furthermore, it can be seen from Figs. 5 and 6 that thickening takes place towards the upper part of the cup with a maximum value of 16 % at the combination of P2 with D1 followed by the combination of P3 with D1 of a value 12.8 %.

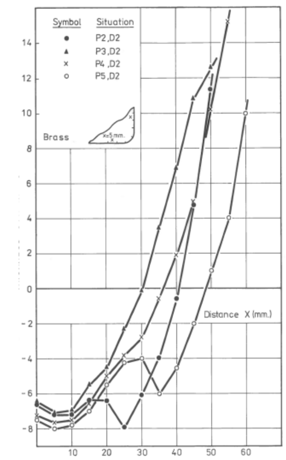

Fig. 5. : Effect of punch profile radius on the thickness strain distribution

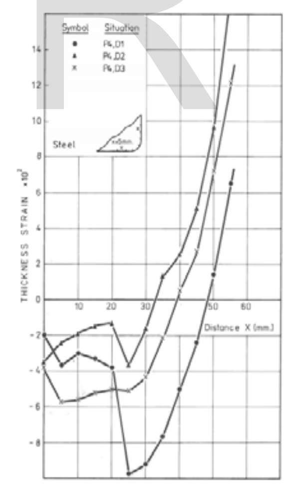

Fig. 6. Effect of punch profile radius on the thickness strain distribution

3.4 Effect of punch profile radius on the maximum drawing force

It can be seen from Fig. 8 that for all values of punches profile radii the maximum drawing force increases with the increase of die profile radius for successfully produced cups and dies combinations. However, it was observed that its liability for wrinkling increased. Furthermore, it can be seen with reference to Figs. 3 and 4 that the force also increases with the increase of the distance of the punch travel and it is not possible to produce successful cups for a die profile radius less than

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2 mm irrespective of the punch profile radius which corresponds to five times the original sheet thickness. Similarly, it is not possible to produce successful cups if the die profile radius is larger than 6 mm which corresponds to 15 times the original sheet thickness. These values are in agreement with the previously reported values for galvanized steel Ref. [27]. Furthermore the effect of the punch profile radius is unlike the die profile radius where the maximum drawing force decreases with increase of the punch profile radius, [27].

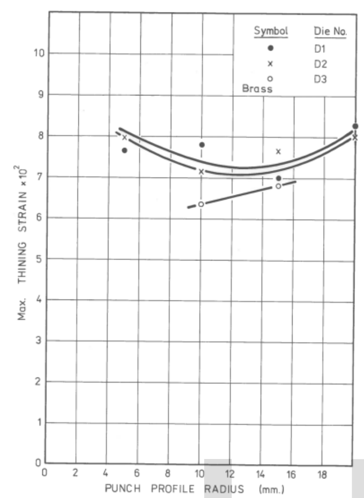

Fig. 7. Effect of punch profile radius on the maximum amount of thinning

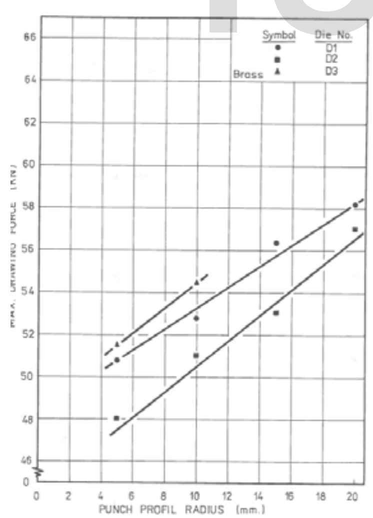

Fig. 8. Effect of punch profile radius on the maximum drawing force

3.5 Effect of Punch Profile Radius on the total consumed work

Examination of Fig. 9 reveals that in general, the total consumed work represented by the area under the autographic record as measured by the planemeter does not follow a general trend. It depends on its combination with the die, for example, it decreases with increase of punch profile radius in a linear manner up to 10 mm after which it starts to increase with increse of the punch profile radius when it is assembled with dienumber 1, D1, although the maximum drawing force was in-creased as explained in the previous section. Also, it can be seen from this figure that the total work does not follow a trend when it is assembled with die number 2, D2. Hence it can be concluded that the total consumed work is very much affected by the die profile radius more than the punch profile radius. This is attributed to the work consumed in the plastic deformation which is much more in the case of the die profile radius the great majority of the sheet will be bent over the die profile radius (the part which forms the cup wall) as compared to a small part of the sheet which will bend over the punch profile radius which forms the cup corner.

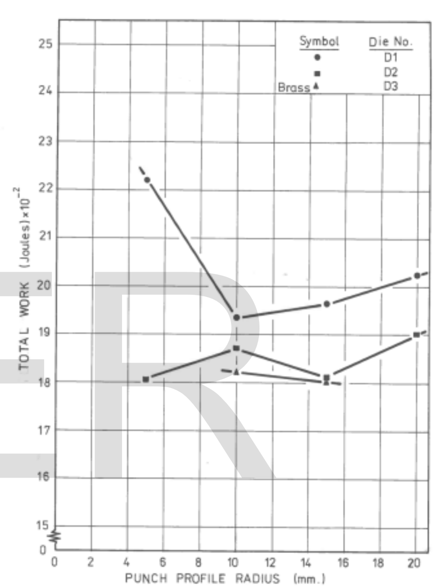

Fig. 9. Effect of punch profile radius on the total consumed work

4 Conclusion

Within the experimental limitations and keeping all the parameters involved in the process constants at their optimal values except the punch and die profile radii the following points are concluded:

i). The minimum amount of thinning occurred at 12 mm punch profile radius when the punch is assembled with dies 1 and 2.

ii). The maximum drawing force is greatly influenced by the punch profile radius in the following manner: it decreases with increase of the punch profile radius irrespective of its assembly with any of the dies. Furthermore, the maximum drawing force is less affected by the punch profile radius as compared to the die profile radius.

iii). The total consumed work does not follow a general trend. It depends on its combination with the die.

iv). Despite the fact that the research work on deep drawing has been going on since 1939, it is far from being complete and the parameters are still not optimized to get rid of the encountered defects in the produced parts and renders the process cost effective.

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