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Experimental Investigation on Locally Increasing the Thickness of Sheet Metal by Beading and Compression Technique

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Abstract

In this study, the possibility of locally increasing the thickness of sheet metal by beading process followed by compression is investigated. Several parameters are considered such as bead height, die width, sheet thickness, forming process iteration, material type and lubrication. The effects of these parameters on the deformation behavior during compression process of the sheet metal are examined. Results show that an appreciable amount of local increase in thickness is possible under optimum conditions of bead height and number of process iteration. Also, the application of lubricant enhances the uniformity of thickness distribution along the bead area.

Keywords: sheet metal, beading, compression, bead height

1. Introduction

In recent years, several changes in production efforts have been observed in the metal stamping industry. Among these are the production of small lots, processes with increasing flexibility aimed to produce complex shapes, development of innovative processes characterized by cheaper equipment, shorter set-up operations and combined and simplified processes (Alberti and Fratini, 2004). For instance, in the field of deep drawing, several innovative techniques have been investigated and tested with the objectives of increasing the forming limits, adaptability to small lots productions, environmentally-friendly processes and others (Hassan, *et al*. 2003; Manabe, *et al*. 2005 and Moon, *et al*. 2001).

The present study attempts to investigate the possibility of locally increasing the thickness of sheet metal based on the concept of Japanese traditional metal craft forming. In this traditional forming process, a highly skilled craftsman employs various techniques to produce such intricate and sophisticated metal crafts (Masahiko, *et al.* 1986 and Nihon Kogekai, 1999). By subjecting sheet metals into hammering process in thickness direction, the sheet can be bent, bulged or drawn into several shapes or desired products. Depending on the intricacy of the product, hammering of the sheets against different types of anvil is repeated dozens of times (Nihon Kogekai, 1999). If the thickness of the sheet can be locally increased, the sheet then can be strengthened locally and hence, will find several applications in the sheet metal industry.

As a new forming technique, locally increasing of thickness is carried out by beading process and compression. In beading process, the sheet metal is allowed to move freely towards the center of the die utilizing a hemispherical punch. The beaded portion is then slowly compressed downward with a flat surface tool while keeping the undeformed portion fixed. The amount of increase in thickness depends on the bead height. At higher bead, greater volume of metal is available for compression. However, too much bead height leads to failure due to buckling of metal during compression. In this study, beading process and compression are conducted to aluminum sheet metals. Parameters considered are bead height, die width, forming process iteration, sheet thickness and lubrication. The effects of these parameters on the deformation behavior during compression as well as on the possibility of locally increasing the thickness are examined.

2. Methodology

Soft aluminum (Al-O) and Al-H of width, b=40mm and length, l=60mm are used as specimens in the experiment. The mechanical properties of these materials are shown in Table 1. In Figure 1, the schematic on how to increase the sheet thickness locally by beading and compression is shown. At the start of the process, the blank is placed between the blankholder and the beading die as shown in Figure 1(a). The clearance between the holder and die is slightly larger than the sheet thickness of the specimen. This will allow the material inside the die to flow freely towards the center as the punch is moved to a specified height, Figure 1(b). In beading process, the thickness of the specimen is kept unchanged. During compression, the beaded specimen is placed in a flat plate. Using a holder, the unbeaded portion is not allowed to move (fixed) as the bead portion is compressed with a flat-surface punch, Figure 1(c). This resulted to an increase in thickness in the bead portion after compression, as shown in Figure 1(d).

Table 1. Mechanical properties of materials

Mechanical Properties	Material	
	Al-O	Al-H
Yield strength, σ_{ys} (MPa)	30.0	119.3
Tensile strength, σ_{ts} (MPa)	82.3	123.3
Total elongation	0.37	0.10
Plastic coefficient, *F* (MPa)	137.1	141.
Work hardening coefficient, *n*	0.195	0.029

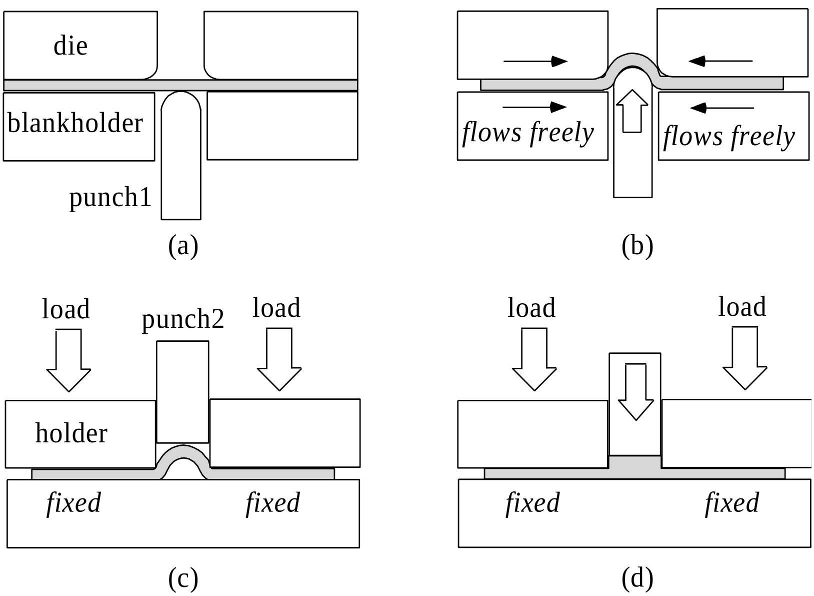


Figure. 1. A schematic on locally increasing the thickness of sheet metal by beading and compression processes. (a) The blank is placed between the holder and die. The clearance between the die and holder is slightly greater than the blank thickness. (b) The punch is moved upward to a specified height forming the bead in the material. (c) The beaded blank is prepared for compression process. The bead portion is then slowly compressed with a flat-surface punch while keeping the unbeaded portion fixed. (d) The thickness in the bead portion is increased after compression.

During the beading process, dies with width w=6mm and 12mm are utilized with die shoulder radius of 2mm and punch diameter of 3mm. In compression, the die widths are 10mm and 16mm. With an objective of achieving more increase in thickness along the bead area, iteration of beading and compression forming process is also carried out. Likewise, the effect of lubrication is also examined. This is done by applying Teflon sheet between the surface of the tools and specimen.

3. Results and Discussion

3.1 Influences of Bead Height and Die Width

Figure 2 shows the deformation behavior at various compression strokes, s, of Al-O material. At die widths of 6mm and 10mm for beading and compression, respectively, as shown in Figure 2(a), the maximum bead height is 4mm. At height greater than this, buckling in the bead area occurs during compression. As the compression stroke is increased, the die shoulder area of the bead becomes flattened. The profile of the bead remains the same, but is getting smaller. At s=1.5mm, the upper surface of the bead becomes flat. The width of the bead is almost constant as the bead height gets smaller as compression proceeds. At s=4mm, the material is almost flattened. The thickness strain distribution during the compression process is shown in Figure 3(a). The thickness in the bead area increases as the compression stroke is increased. However, the amount of increase in the center of the bead is relatively small.

The influence of die width is also investigated by using a width of 12mm and 16mm for beading and compression, respectively, as shown in Figure 2(b) and Figure 3(b). Results show that there is a similar deformation behavior of the material during compression with the two sets of die width. However, the maximum bead height is increased to 6mm.

Figure 4 shows the thickness strain distribution at various bead heights, h, after the compression process for both die widths. It is shown that as the bead height is increased; the thickness in the bead area correspondingly increases. However, at larger h, the amount of increase is not uniform.

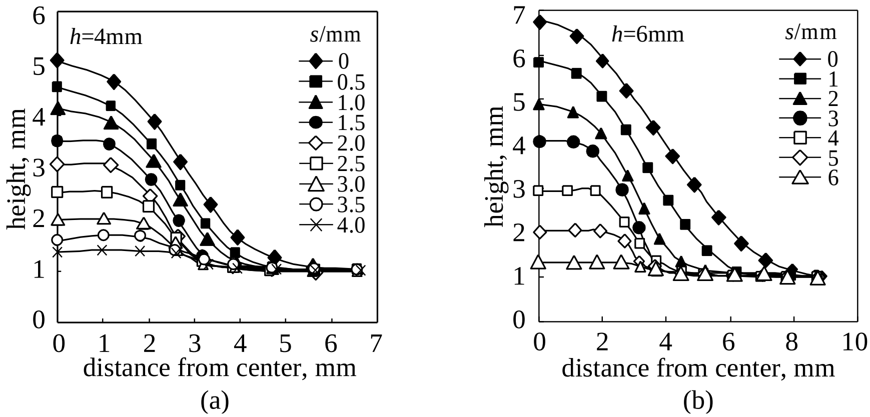


Figure 2. Deformation behavior of Al-O(t=1mm) at various compression strokes, *s*, utilizing (a) beading die width=6mm; compression die width=10mm (bead height=4mm) and (b) beading die width=12mm; compression die width=16mm (bead height=6mm).

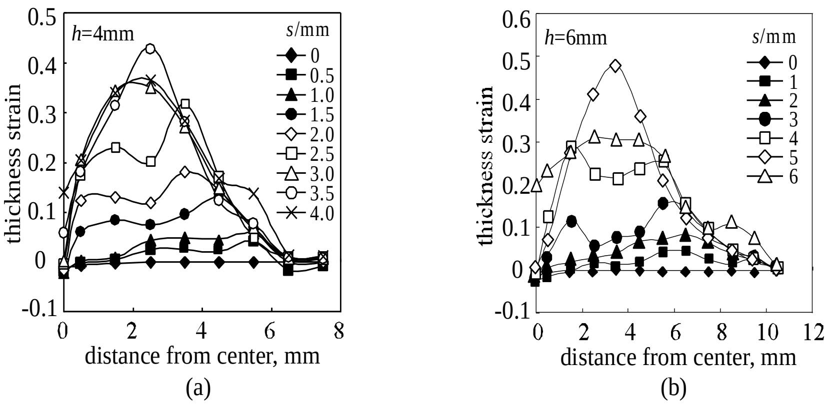


Figure 3. Thickness strain distribution at various compression strokes, *s*, utilizing (a) beading die width=6mm; compression die width=10mm (bead height=4mm) and (b) beading die width=12mm; compression die width=16mm (bead height=6mm).

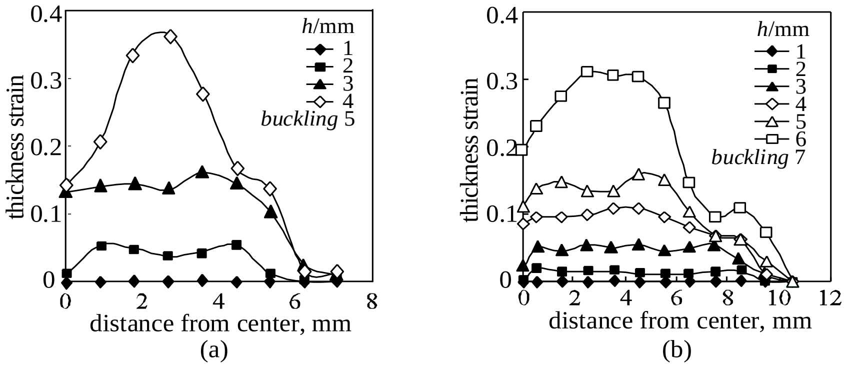


Figure 4. Thickness strain distribution at various bead heights, *h*, after compression utilizing (a) beading die width=6mm; compression die width=10mm (bead height=4mm) and (b) beading die width=12mm; compression die width=16mm (bead height=6mm).

3.2 Influence of Forming Process Iteration

Figure 5(a) shows the thickness strain distribution after compression at several number of forming process iteration, *m*, at bead height of 3mm. The final shape of the specimens is shown in Figure 5(b). As shown in both figures, the local area thickness is increased as the number of forming iteration is also increased. However, the thickness in bead center decreases at the lower surface with increasing number of iteration.

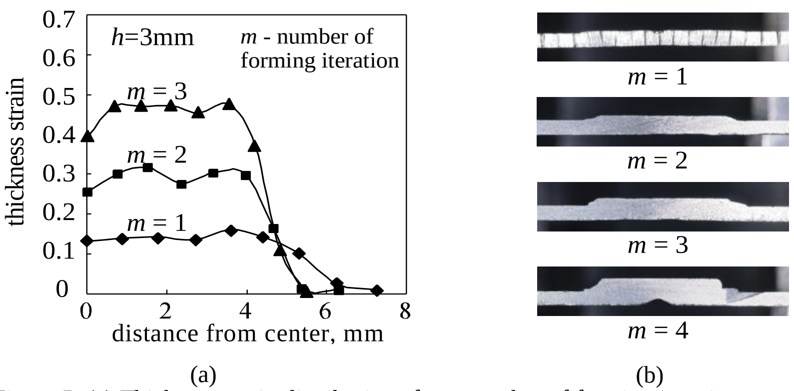


Figure 5. (a) Thickness strain distribution after a number of forming iteration, *m*, at a bead height of 3mm (beading die width = 6mm; compression die width = 10mm; Al-O; t = 1mm). (b) Final shape of the specimen at several number of forming iteration, *m*.

This may be due to the excessive amount of plastic deformation that is induced in the material due to forming repetition.

3.3 Influence of Material Properties

Figure 6 shows the thickness strain distribution after compression at different bead heights for Al-O and Al-H materials. Thickness increases with bead height. At *h*=4mm, the increase in thickness for Al-H is comparatively more uniform than Al-O. This is due to the differences in material characteristics such as the *n*-value. At *h*=5mm, flattening of the bead area fails due to buckling.

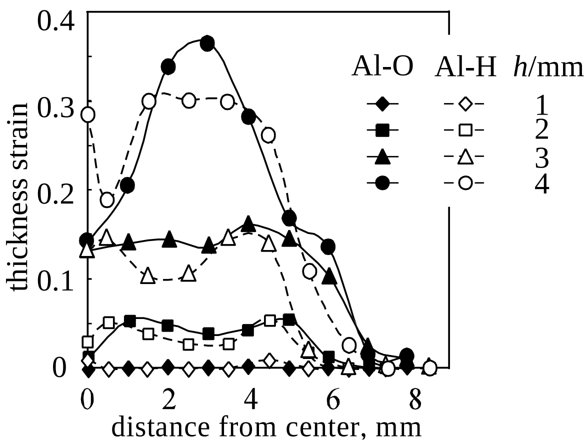
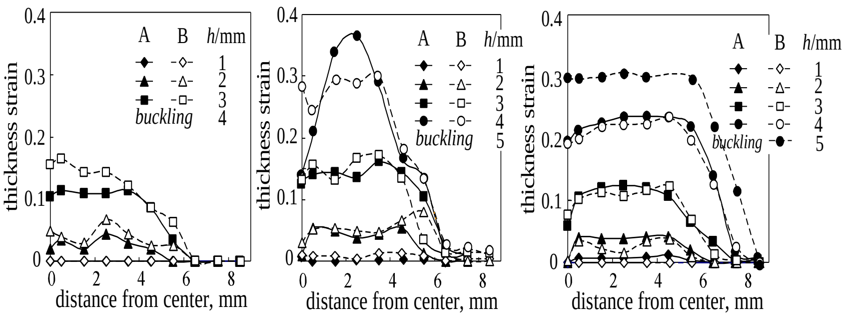


Figure 6. Effect of material type on the thickness strain distribution at different bead height, *h*, after compression. (t=1mm)

3.4 Influences of Initial Thickness and Lubrication

Al-O material with thickness of 0.5mm, 1mm and 1.5mm is utilized in examining the effect of initial thickness. Figure 7 (A: no lubrication) shows the results. In all cases, as the bead height increases, thickness also increases. At *h*=3mm, it is observed that the thickness strain distribution of all sheet thickness considered are almost the same. For specimen with thickness of 0.5mm, buckling occurs at *h*=4mm. On the other hand, buckling occurs at *h*=5mm for specimens with thickness of 1mm and 1.5mm.

In an attempt to minimize the non-uniformity in the distribution of thickness increase, Teflon sheet is used as lubricant between the tools and specimen. Results are shown in Figure 7 (B: with lubrication). Improvements are observed when the lubricant is used. At t=0.5mm and 1mm, the thickness in the bead center is comparatively increased resulting to a more uniform thickness distribution. In the case of t=1.5mm, at *h*=5mm, the thickness distribution is very uniform whereas if no lubricant is applied, buckling will occur at this bead height. Figure 8 shows the final shape of the specimens with lubrication.



(a) t = 0.5mm (b) t = 1mm (c) t = 1.5mm

Figure 7. Effect of lubrication (A: no lubrication; B: with lubrication) on thickness strain distribution at various bead heights, *h*, after compression of Al-O with sheet thickness of (a) t=0.5mm; (b) t=1mm; and (c) t=1.5mm.

t=0.5mm; *h*=3mm

t=1mm; *h*=4mm

t=1.5mm; *h*=4mm

t=0.5mm; *h*=4mm

t=1mm; *h*=5mm

t=1.5mm; *h*=5mm

Figure 8. Final shape of the specimens at various sheet thickness and bead heights after compression with lubrication

4. Conclusion and Recommendation

This investigation demonstrates interesting and promising results on locally increasing the thickness of sheet material by beading and compression technique. As found in this study, several parameters influence the success of this forming method. Appropriate bead height and number of forming iteration should be utilized in order to attain a successful and appreciable increase in thickness along the bead area. Lubricant should also be applied to enhance uniformity in the thickness distribution. Further investigation should be conducted to substantiate the preliminary results found in this study as well as to validate the feasibility and applicability of this unique forming technique.

5. Acknowledgement

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6. References

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