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FORMABILITY OF COMBINED STRETCHING PROCESSES WITH SIMULTANEOUS COMPRESSION

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Abstract

In order to restrain the local necking during stretching of sheet metals, the combined stretching processes with simultaneous compression are proposed. The combined stretching tests with two types of compression to top of the cup were carried out using the pure aluminum sheets; (1) stroke control loading process and (2) pinpoint loading process. It was clarified that the metal flow in the cross-section of the cup is affected significantly both by the magnitude of load and the stroke in the compression process. It was also found that the local necking can be restrained effectively by the metal flow from center of the cup and therefore the forming limit is improved.

Key words : sheet metal forming, stretching, metal flow, forming limit

1. Introduction

Recently, flow forming [1] for sheet metal have been practically employed on the metal forming in order to decrease the weight of products and to save several steps of the processes. Some experimental studies [2, 3] were reported that the forging process was employed by increasing thickness of sidewall on deep drawing. These processes which were recognized as the new processes to avoid buckling of sheet blank, i.e., sheet metal forging.

Stretching, one of the sheet forming, is a forming process of balanced biaxial tension. However, there are some difficult problems that the forming limit is determined by the ductility of materials owing to no metal flow from the flange position.

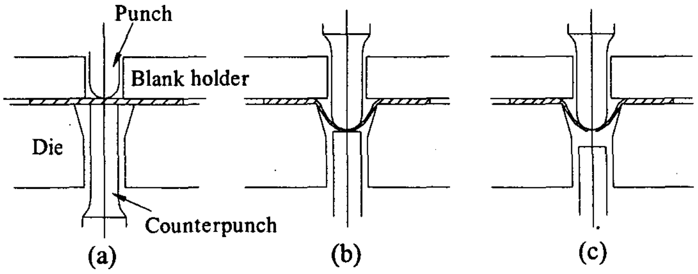
In this study, the authors proposed new forming processes which can avoid the local decrease in the thickness caused by the ductility limit. Two types of combined stretching tests were carried out using pure aluminum ; (1) stroke control loading and (2) pinpoint loading. The authors also refer the process as “combined stretching process” with compressing on the central part of cups which contacts with upper punch. By using this process, it is considered to be favorable that forming limit becomes higher.

2. An outline of combined stretching

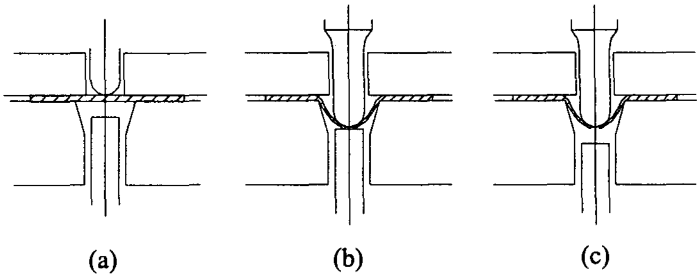
Fig.1 shows the schematic illustration of the combined stretching. It is difficult to decrease thickness of the central part of the cup owing to the friction above the punch under the conventional stretching.

By using the combined stretching process, the material in this area flows toward the side wall by compression and the local necking or thinning of the side wall is restrained.

In stroke control loading, compression is imposed simultaneously as the stretching process starts. On the way of the process, the compression process is finished but the stretching process still remains. In pinpoint loading, the compression process operates at a certain stroke during the stretching process.



(1) Stroke control loading



(2) Pinpoint loading

Fig.1 Schematic illustration of combined stretching tests.
(a) *Start,* (b) *Forming,* (c) *Finish*

3. Experimental procedures

3.1 Experimental conditions

A press simulator having the capacity of 500kN was used for the tests.

A punch with 11 mm and a die with 15 mm in diameter were used. The blank holding pressure was applied by four coil springs.

In order to compress the central part of the cup, counterpunch with 10 mm in diameter was set at the opposite side of the punch. All the experimental conditions are given in Table 1.

Table 1 Experimental conditions

Name	Material	Experimental condition
Punch	HAP40 HRC=60～62	Punch diameter *Dp* =11mm Spherical head
Die	SKD11 HRC=60～62	Inner diameter *Dd* =15mm Taper angle α =15°
Counter punch	HAP40 HRC=60～62	Punch diameter *D* =10.0mm
Lubricant	Sanwa Yuka Co.Ltd. Omega Type 500 [512mm2/s(40℃)]	

3.2 Stroke control loading

Fig.2 shows an example of load-stroke diagram under the stroke control loading. At the same time of stretching using the punch, compression process using the counterpunch begins. A counterpunch load "*Pc*" is kept constant until a stoke reaches to the desired stroke "*Lc*", and after that, the conventional stretch forming is continued.

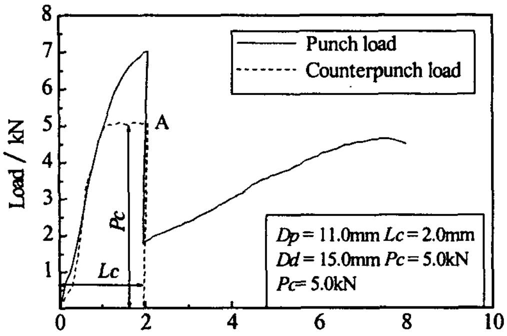


Fig.2 An example of load –stroke diagram under stroke control loading

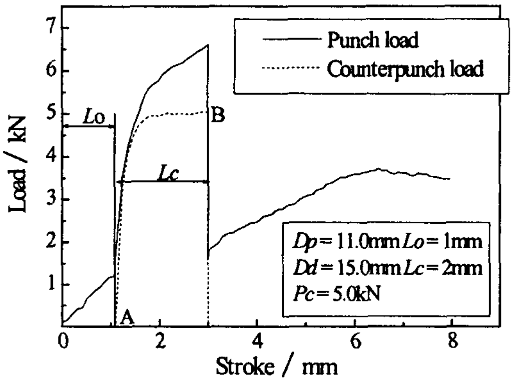


Fig.3 An example of load –stroke diagram under pinpoint loading

3.3 Pinpoint loading

Fig.3 shows an example of load-stroke diagram under the pinpoint loading. When the stroke arrives at a point A, called "compression starting stroke L_0", compression begines with the counterpunch. The load is kept constant in a desired stroke *Lc* up to point B and after that, the conventional stretch forming is continued.

4. Results and discussion

4.1 Thickness distribution of formed cups

Fig.4 shows the thickness distribution of cups with various stroke parameter *Lc* under the stroke control loading process. It can be seen that the thickness of cups is minimum at 5mm from the center for *Lc* of 2.0mm or less. We refer these portions as "necking point". But, when the parameter *Lc* is larger than 2.0mm, the thickness of cups around this location increases and the necking point disappears.

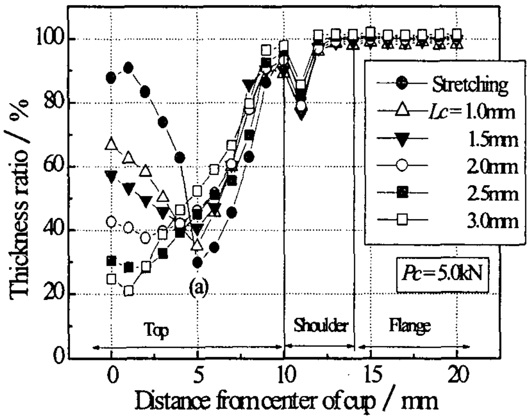


Fig.4 Thickness distribution under stroke control loading

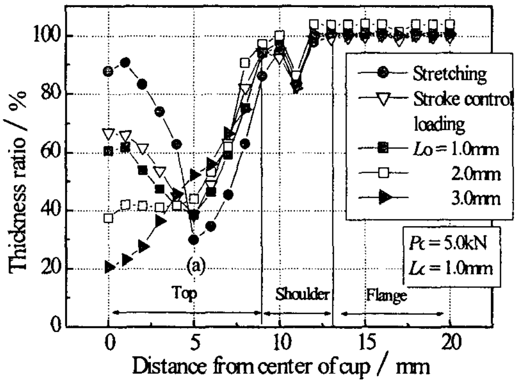


Fig.5 Thickness distribution under pinpoint loading

Fig.5 shows the thickness distribution of cups under the pinpoint loading process. When the stroke parameter L_0 is larger than 2.0mm, the thickness of the necking point is increased.

Fig.6 shows the examples of photographs (upside-down image) of formed cups for various forming process. It is clearly seen that the necking of side wall of cups formed by the stroke control loading and the pinpoint loading disappears.

(a) stretching Lc=1mm (b) stroke control Lc=1mm, (c) pinpoint L_0=2mm

Fig.6 The examples of photographs of cups (Pc=5.0kN)

4.2 Metal flow of cups

Fig.7 shows the thickness ratio of cups with various stroke parameter Lc under the stroke control loading process. The thickness ratio was defined as the ratio of the thickness of cups formed by the stroke control loading process to ones by conventional stretching.

It is found that the thickness shows the minimum in the central part and the maximum at the necking point. Therefore, the metal flow occurs from the central part to around necking point. No metal flow is observed at the shoulders and the flange part. Furthermore, it is seen that the metal flow increases with increasing stroke parameter Lc.

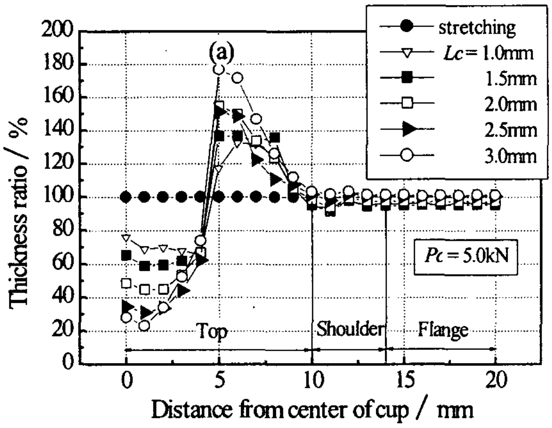


Fig.7 Thickness distribution under stroke control loading

4.3 Improvement of forming limit

Fig.8 shows the relationship between the thickness at the center and stroke parameter Lc with various counterpunch load Pc.

The thickness decreased linearly with increasing Lc.

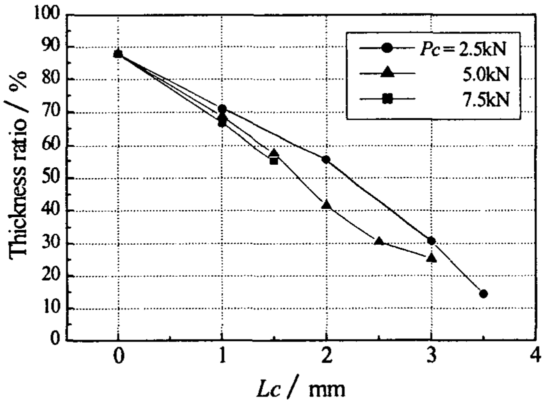


Fig.8 Variation in thickness at center with stroke parameter Lc

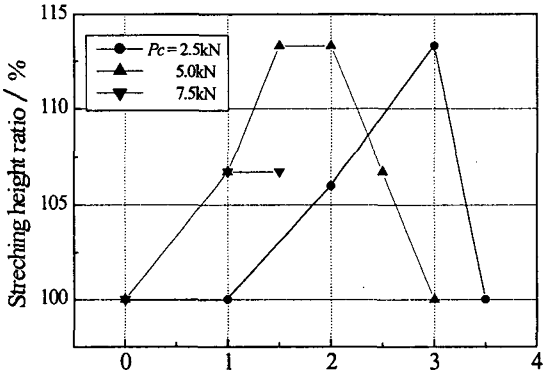


Fig.9 Variation in stretching height ratio with stroke parameter Lc

Fig.9 shows the relationship between the stretching height ratio and stroke parameter *Lc*. The stretching height ratio was defined as the ratio of the height of cups formed by the stroke control loading process to ones by conventional stretching. It can be seen that an optimum stroke of *Lc* exists to improve the stretching height. In this investigation, the stretching height ratio increases by about 13%.

5. Conclusions

In order to restrain the local necking during the stretching of sheet metals, the combined stretching processes with simultaneous compression are proposed. The following results are obtained.

(1) The metal flow from the central part to the necking point is observed clearly under both the stroke control loading and the pinpoint loading.
(2) The magnitude of metal flow is closely related to the stroke parameter *Lc*, L_0 and the counterpunch load *Pc*.
(3) The forming limit under the stroke control loading process was improved at an optimum *Lc*.

References

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