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Lateral extrusion of tailor welded aluminum alloy pipes with a lost core of low temperature melting alloy

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ABSTRACT

Purpose: In this paper, the authors employ tailor welded aluminum alloy pipes for lateral extrusion process with a lost core to perform a hollow light-weight-part.

Design/methodology/approach: The pipe is welded longitudinally by YAG-laser. “The lateral extrusion process with a lost core (LELC)” consists of lateral extrusion of pipes with a soluble solid core, called the “lost core”, which serves as a plastic mandrel. The process proceeds as follows. First, the pipe cavity is filled with the liquid low temperature melting material composing the lost core. The liquid is then solidified to form the soluble core of the pipe. The material is compressed longitudinally as a composite billet as well as forging, and extruded in the lateral direction. After the pipe is deformed, the lost core is melted and removed. s. The bulge by the LELC is carried out by extruding the material for the lateral direction, however the simple bulge by hydro-forming is done by internal pressure.

Findings: The LELC process can make a hollow product having uneven wall thickness without the deformation concentrating on a thinner part of the material, because the circumferential deformation of the material will be performed by its meridian strain.

Practical implications: The authors have developed LELC process in which the lost core consists of low-temperature melting alloys and have tried to apply the process to perform bulge process with a tailor-welded pipe having two different wall thickness.

Originality/value: Optimum volume distribution is important for light-weight-parts, and employment of tailor-welded blanks is effective technique in sheet metal forming. Combination of employment of hollow shape and tailor-welded blanks seems to be hopeful.

Keywords: Tube forming; Tailored blank; Lateral extrusion; Bulging; Hollow product

1. Introduction

Tube forming technology, especially bulge processes, has become more and more important today for producing hollow shape to obtain light products, and most popular bulge processes employ a hydro-forming process. On the other hand, optimum volume distribution is important for light-weight-parts, and employment of tailor-welded blanks is effective technique in sheet metal forming. Therefore, combination of employment of hollow shape and tailor-welded blanks seems to be hopeful. However, it is not easy because the deformation tend to concentrate on a thinner part in hydro-forming.

The authors have developed a lateral extrusion with a lost core (LELC) process in which the lost core consists of low-temperature melting alloys [1-2], and have tried to apply the process to perform bulge process with a tailor-welded pipe having two different wall thickness.

2. Outline of lateral extrusion with a lost core

2.1. Basic schema

The basic schema of "the lateral extrusion process with a lost core (LELC)" discussed in this paper is illustrated in Fig. 1. In the process, a hollow pipe is filled by a soluble solid core made of a low-temperature melting material, and is extruded laterally with the core. The core is then melted and removed after the final product is formed. The process can produce large bulged diameter because the solid core acts as a plastic mandrel inside the pipe [1], and protects the pipe against unstable deformation by wrinkling. The process can be performed with plain press machines and dies for forging.

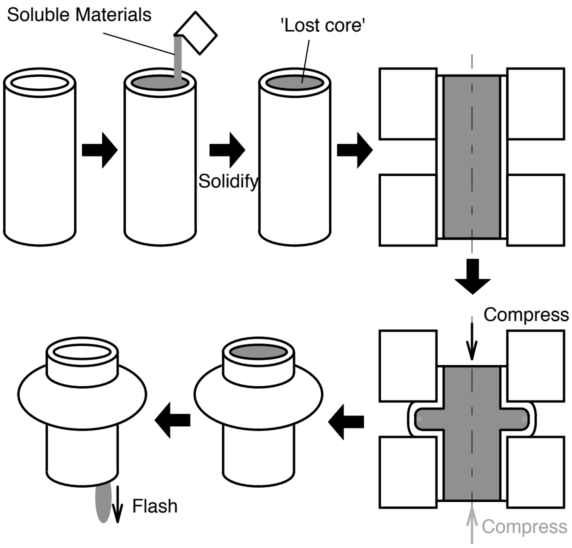


Fig. 1 Lateral extrusion with a lost core [1-2]

2.2. Difference from hydro-forming

Figure 2 shows the typical distributions of the strain of formed pipes compiled from experiments of the LELC. The strains are calculated by the following Equations[2].

$$\varepsilon_n = LN\left(\frac{t}{T}\right) \quad (1)$$

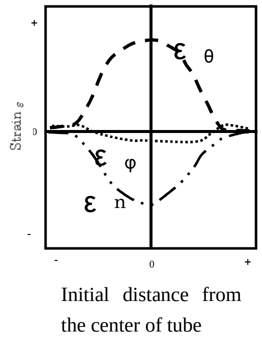
t: Thickness of wall after forming
T: Initial thickness of the wall

$$\varepsilon_\theta = LN\left(\frac{d}{D}\right) \quad (2)$$

d: Bulged diameter
D: Initial diameter

$$\varepsilon_\phi = -(\varepsilon_n + \varepsilon_\theta) \quad (3)$$

a)



b)

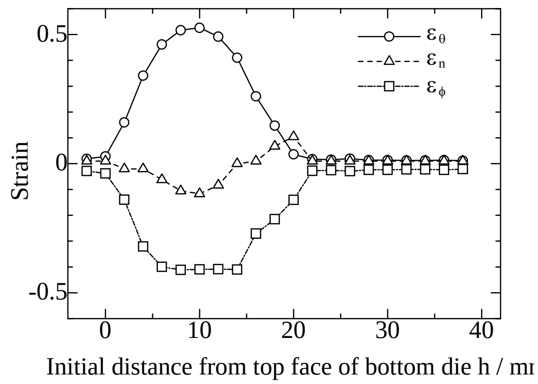
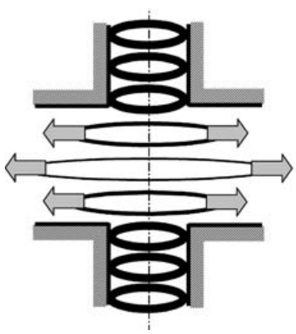


Fig. 2 Typical distributions of the strain [2]: a) hydro-forming, b) proposed process

We can observe an uneven distribution of ε_ϕ for the lateral extrusion as well as with the lost core of the low-temperature melting alloys [3]. Furthermore, ε_ν remains small in the gap. Together, these indicate that the sample is deformed under conditions close to the two-dimensional state of stress. In contrast to the result for a simple hydro-forming bulge process without axial compression, ε_θ is much smaller and ε_θ is much larger. This indicates that the bulge by the LELC is carried out by extruding the material from the upper dies, however the simple bulge by hydro-forming is done by internal pressure. These differences are shown in Fig. 3.

a)



b)

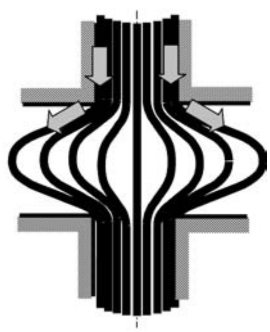


Fig. 3. Typical deformation mechanism [2]: a) hydro-forming without axial compression, b) LELC

On the above mechanism, the authors think that the LELC process can make a hollow product having uneven wall thickness without the deformation concentrating on a thinner part of the material, because the circumferential deformation of the material will be performed by its meridian strain. The authors confirm it by experiments mentioned in the following chapters.

3. Experimental conditions

Figure 4 shows the drawing of a test piece. The authors prepare the test piece in two ways. The one is hollowed out from an A5056 rod (see Table 1) by a wire-cutting machine. The other is from welded pipes having different thickness by a YAG-laser welder. The former is employed for observation of material deformation without regarding the influence of the welding.

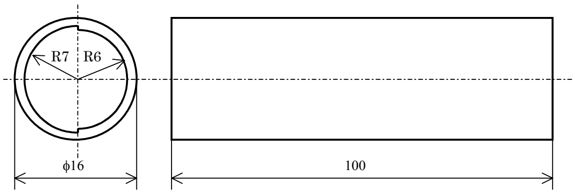


Fig. 4. Test piece

Table 1.
Chemical composition (wt.%) of A5056 aluminum alloy

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
0.30≥	0.4≥	0.1≥	0.05-0.20	4.5-5.6	0.05-0.20	0.10≥	0.05≥

Figure 5 shows dies. The gap between upper and lower dies changes by changing the spacer. Table 2 shows experimental conditions. A test peace is marked with circumferential lines of 1mm interval and lines of longitude of 18-degree interval. Distribution of thickness of a specimen is measured at the cross point of these lines with a ultrasonic thickness meter after the experiment. Radius from center axis is also measured at every same point with a measuring microscope.

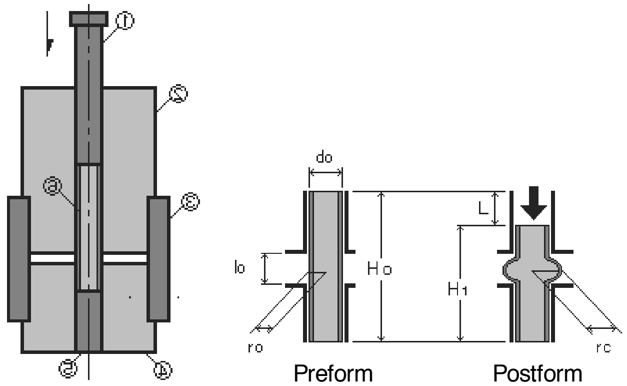


Fig. 5. Dies and specimen: 1-Punch, 2-Upper die, 3-Spacer, 4-Lower die, 5-Knock-out punch

Table 2.
Experimental conditions

Testing machine	1000KN universal testing machine
Head speed / mm·min^{-1}	1.0
Forming temperature	Room temperature
Lost core	$Bi_{49}Pb_{18}Sn_{12}In_{21}$ (MP58°C)
Lubricant	Moripaste (Sumico Lubricant Co.)

4. Result and discussions

Figure 6 shows specimens with different gap with same punch stroke. We can see that both specimen has almost even bulged disc. represents Figures 7, 8 and 9 show strain distributions. Angle R6αR7 represents circumferential location. The center of a thick part and the center of a thin part are 0 degrees and 180 degrees respectively. Circumferential strain ε_θ of the thinner part is little bit larger than the other part, however the difference is quite small. Reduction of thickness ε_n is much smaller than the other strains. It represents the bulge is not performed by reduction of the thickness but by meridian strain mainly. Reduction of the thickness seems to be a little bit larger in the thin part than in the thick part. Distribution of the meridian strain is varied, and a remarkable tendency by the thickness of the wall is not seen. The authors think that the difference of the bulge between the thick and thin part comes from the difference of reduction of thickness. The thin part is elongated more than the thick part because of circumferential tension slightly. Weld line on the bulge tends to lean to thick side. However, the LELC process can make a hollow product having uneven wall thickness without the significant deformation concentrating on a thinner part of the material. Figure 10 shows hardness distribution of the surface of employed tailor-welded pipe. Figures 11 and 12 show forming limit of the specimen. HAZ is observed in Fig. 10, and crack is occurred at the center of weld line. Then the authors anneal the specimen before bulging to remove HAZ (345°C, 5min, air cooled). However, the result is not improved. Joint strength of the welding is a problem rather than HAZ in this case. In addition, it is not easy to keep quality of welding of such the thin tube stable generally in actual production. Therefore we must consider to use extruded special pipe instead of welded one to carry out large bulge stably.

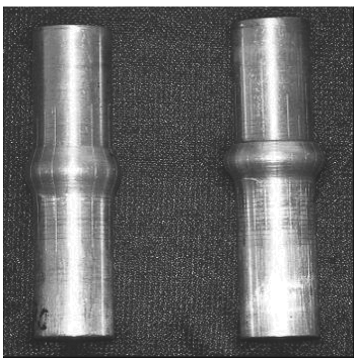


Fig. 6. Formed specimens (punch stroke 4.1mm)

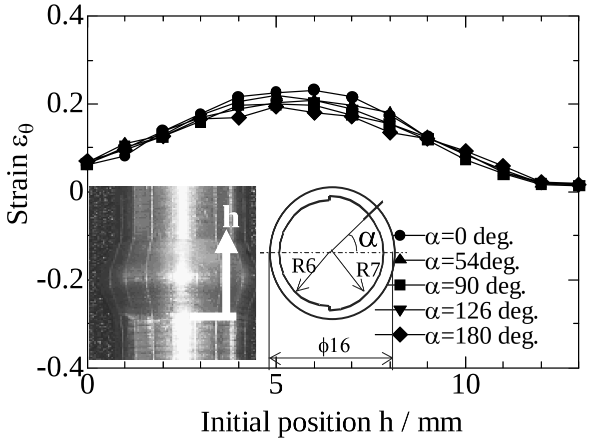


Fig. 7. Circumference strain (Gap 8mm, Punch stroke 4.1mm)

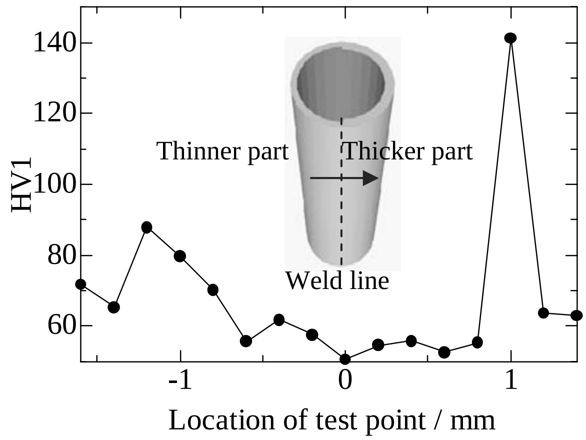


Fig. 10. Hardness distribution on the weld line

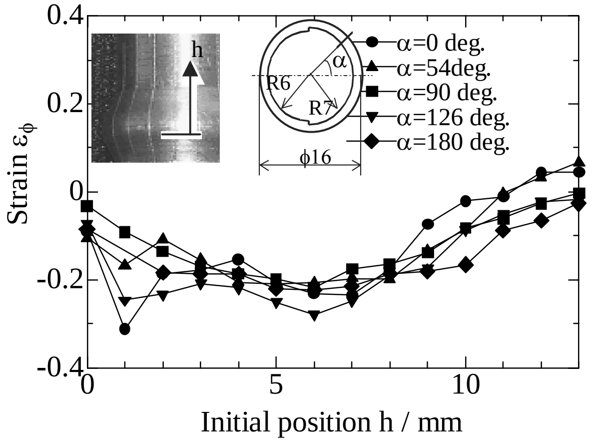


Fig. 8. Meridian strain (Gap 8mm, Punch stroke 4.1mm)

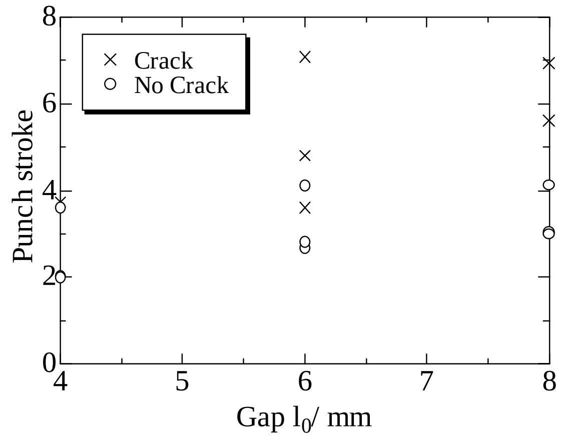


Fig. 11. Forming limit (wire-cut type pipe)

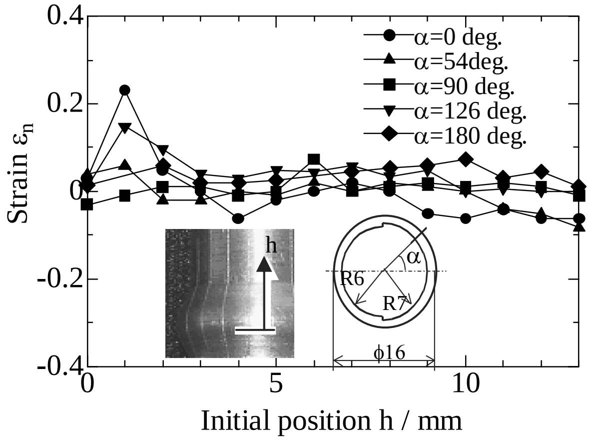


Fig. 9. Reduction of thickness (Gap 8mm, Punch stroke 4.1mm)

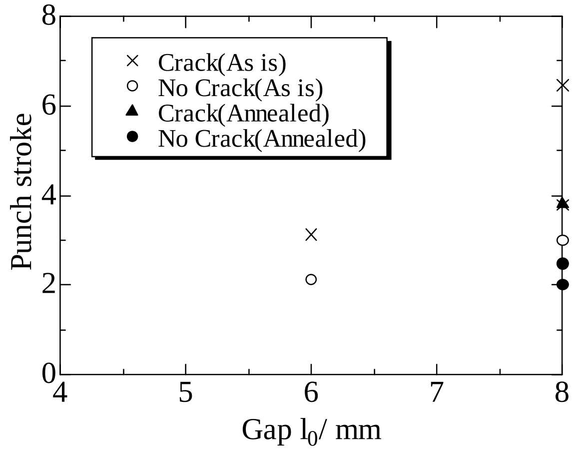


Fig. 12. Forming limit (weld type pipe)

5. Conclusions

Optimum volume distribution is important for light-weight-parts, and employment of tailor-welded blanks is effective technique in sheet metal forming. Combination of employment of bulge process and tailor-welded blanks is not easy because the deformation tend to concentrate on a thinner part in hydro-forming.

The authors have developed a lateral extrusion with a lost core (LELC) process in which the lost core consists of low-temperature melting alloys. In this paper, the authors confirms that the LELC process can make a hollow product having uneven wall thickness without the deformation concentrating on a thinner part of the material, because the circumferential deformation of the material will be performed by its meridian strain.

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