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Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

The mold-less casting technique for production of the wrought aluminum alloy components

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This paper describes design freedom, dimensional accuracy, solidification structures and mechanical properties of hollow products of A6063 aluminum alloy fabricated by the mold-less casting technique. Kinds of geometries, such as a pipe with inner ribs, were fabricated by this process. High thickness accuracy was achieved when a thermally stable condition was maintained. Ultimate tensile strength, proof strength and fracture strain of T6 heat treated A6063 alloy fabricated by this technique were as high as those of extrusions.

Keywords: *Wrought aluminum alloys, Complex geometry, Capillary shaping, Directional solidification, Strength*

1. Introduction

In recent years, there have been increasing demands for manufacturing automotive frame components of wrought aluminum alloys (from 2XXX to 7XXX) with complex geometries, in order to improve ride comfort and reduce weight. However, it is difficult to fabricate these frame components by conventional manufacturing techniques.

Mold-less casting is one of the capillary shaping techniques by which products with a hollow and complex geometry are fabricated directly from a melt [1-3]. In this process, a melt column is formed above the melt surface using a starting device and shaping devices (Fig. 1). Then the starting device is withdrawn upward, cooling the position higher than the melt column, so that a top of the melt column continuously solidifies. Product geometries are controlled by a pulling path and a movement of the shaping device. The directional solidification in this process permits shaping of the wrought aluminum alloys with high strength and elongation, despite their high hot-cracking sensitivity.

In this study, design freedom and the dimensional accuracy of A6063 aluminum alloy were investigated. An effect of Ti and B additions into A6063 alloy melt on the solidification structure and mechanical properties were determined.

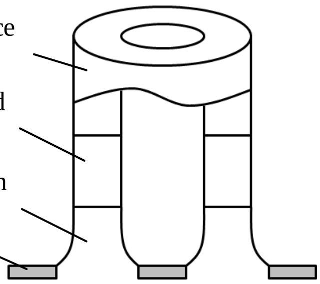

Fig. 1 A schematic of the mold-less casting to fabricate a hollow product.

2. Experimental procedure

Melts of A6063 alloy and grain refined A6063 alloy by inoculation of Al-5Ti-1B master alloy (A6063-Ti) listed in Table 1 were used in this study. Fig. 2 shows an apparatus. Shaping device was placed on the melt, and aluminum alloy melt was withdrawn through an opening of the shaping device using a starting device. Coolant air was blown onto the solidified part by inner and outer cooling nozzles. By changing a pulling path and an opening dimension of the shaping device, specimens with kinds of geometries were fabricated. During the pulling process, melt position was monitored by a melt level sensor in order to control the pulling rate and positioning of the shaping device. In some conditions, the vertical temperature distribution from 140 mm under the melt level to the solidified part was recorded by thermocouples fixed to the starting device.

Solidification structure of the hollow specimens was observed by polarized microscope after anodization treatment (Barker's etching). The hollow specimens of A6063 alloy and A6063-Ti alloy were machined to the tensile test plate specimens with size of 11 mm in the gauge length, 4 mm in width and 2 mm in thick after the T6 heat treatment. Tensile tests were carried out at the 0.005 mm/s in the crosshead speed.

Table 1 Chemical composition of alloys (mass%).

Alloy	Cu	Si	Mg	Fe	Ti	Al
A6063	0.01	0.58	0.74	0.08	0	bal.
A6063-Ti	0.01	0.56	0.74	0.08	0.06	bal.

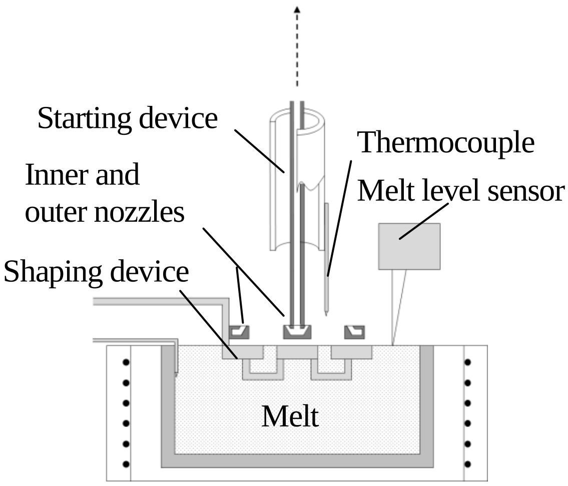

Fig. 2 A schematic of the mold less casting.

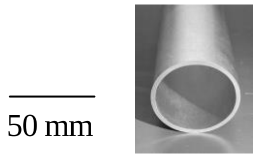

Fig. 4 A specimen with high thickness accuracy.

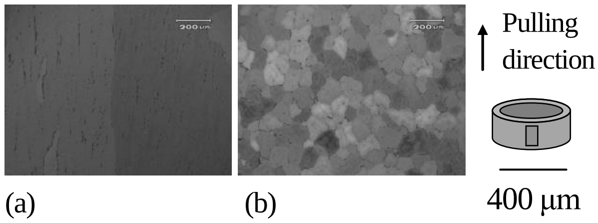

Fig. 5 Microstructures of (a) A6063 alloy and (b) A6063-Ti alloy specimens.

3. Results and discussion

Fig. 3 shows examples of A6063 alloy specimens produced by this process. Hollow specimens with inner ribs (Fig. 3a) and bent geometries (Fig. 3b, 3c) were fabricated by changing the opening dimension of the shaping device and the pulling path.

High thickness accuracy was achieved when the pulling process was conducted under thermally stable condition [3]. A pipe of A6063 alloy with size of 50.6 ± 0.15 mm in outer diameter and 2.6 ± 0.1 in thickness was fabricated at a pulling rate of 1.4 mm/s (Fig. 4).

Fig. 5 shows microstructures of the A6063 and A6063-Ti alloys. The primary dendrite trunks aligned almost antiparallel to the pulling direction for the A6063 alloys specimen, whereas equiaxed grain structure was obtained for the A6063-Ti alloy specimen. Since the directional solidification was macroscopically maintained during the pulling process, no shrinkage porosity was found in the both specimens.

The reported value of tensile properties for the T6 heat treated A6063 extrusions were 240MPa in the ultimate tensile strength, 215MPa in the 0.2% proof strength and 12% in fracture strain [4]. The tensile properties of the T6 heat treated A6063 alloy and A6063-Ti alloy specimens fabricated in this study were as high as those of the extrusions (Fig. 6).

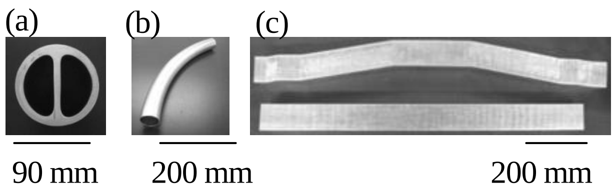

Fig. 3 Examples of (a) a pipe with an inner rib, (b,c) hollow specimens with bent geometries.

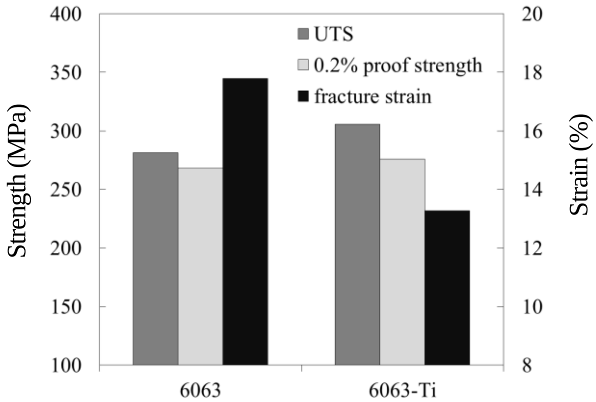

Fig. 6 Tensile properties of the T6 heat treated A6063 alloy and the A6063-Ti alloy specimens.

4. Conclusion

The mold-less casting technique were investigated in order to develop new manufacturing process for the automotive frame components of wrought aluminum alloys with high geometrical complexity. Hollow products with inner ribs and bent geometries of A6063 alloy were fabricated by this technique and high thickness accuracy was achieved. Also high tensile properties were obtained for the T6 heat treated A6063 specimens due to the absence of the shrinkage porosity.

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