properties of the as-cast, homogenized and cold-rolled

Improvement of formability of silicon-containing recycled wrought aluminium by hot stamping after rapid heating

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In this study, Al-Si binary alloys of Al-3%Si, Al-7%Si and Al-12%Si were cast, homogenized and cold-rolled at a reduction ratio of 80%, and then the mechanical properties were evaluated by tensile tests at room temperature. Irrespective of Si content, ultimate tensile strength of the cold-rolled specimens reached 200-210 MPa, although elongation to fracture decreased with increasing Si content. SEM microstructures suggested that the coarsened Si particles are deformed by cold rolling, and then the edges of broken Si particles act as starting points of crack generation, resulting in the earlier fracture of Al-7%Si and Al-12%Si alloys.

On the formability of the cold-rolled specimens, on the other hand, Al-3%Si and Al-7%Si alloys were both successfully V-bent with a bending radius of 9 mm, indicating that the amount of Si particles has less influence on the degradation of formability. However, V-bending of more Si particle containing Al-12%Si alloy could not be accomplished at room temperature, and therefore rapid heating to 250°C became quite effective for improving the formability of Al-12%Si alloy as well as a commercial A4032-T6 alloy. The effectiveness of such a hot stamping method was clarified even in the case of a bending radius of 2 mm; i.e. Al-3%Si alloy can be V-bent at room temperature, whereas rapid heating to 250, 300 and 350°C are needed for Al-7%Si, Al-12Si and A4032-T6 alloys, respectively. Therefore, it was revealed that higher Si content as well as some alloy elements (e.g. Cu and Mg) degrades the formability of Al-Si alloys, but rapid heating before hot stamping can improve the formability of recycled wrought aluminum.

Keywords: *recycled aluminium alloy, Al-Si, rolling, formability, hot stamping*

1. Introduction

To reduce vehicle weight and thus fuel consumption of automobiles, Al-Si alloy (die)castings are used for engine components, whereas Al-Mg-Si and Al-Mg wrought alloys are for panel components. In the present recycling system, however, although most of Al-Si alloy (die)castings are recycled into engine components, the scrap of wrought aluminium alloys is degraded to cast components because Al-Si alloy (die)castings and/or steel-made fasteners are inevitably mixed [1]. This cascade recycling is not only because complete sorting of shredded scrap is high cost, but also because only lower impurity concentrations are allowed in wrought alloys to maintain their ductility and formability. Due to electrification in automobiles, the demand for cast components is decreasing, and therefore application methods of silicon- (and/or iron-) containing wrought aluminium should be rapidly developed to accomplish closed recycling systems for automobiles. In this study, hot stamping after rapid heating to a preset temperature of 350˚C maximum was applied to Al-Si wrought alloys with different Si contents, and then their formability was compared from the viewpoints of Si content, impurity elements and deformation temperature. The purpose of this study is two-fold: To optimize Si content and impurity elements of Al-Si alloys when used as wrought materials, and to develop a method to improve their formability by optimizing hot stamping conditions.

2. Experimental procedures

Al-Si binary alloys with varying Si content (Al-3%Si, Al-7%Si, and Al-12%Si) were cast, homogenized and then cold-rolled at a reduction ratio of 80%. Mechanical specimens were evaluated by tensile tests at room temperature. Microstructural observation using an optical microscope (OM) and scanning electron microscope (SEM) was conducted to clarify the relationship between microstructures and mechanical properties.

To evaluate the formability of the Al-Si alloys, the cold-rolled specimens with a dimension of 150 × 20 × 2 mm^3 were subjected to V-bending at room temperature, or if failed after rapid heating to a preset temperature of 350˚C maximum, as shown in Fig.1. Radii of V-bending were selected at R= 2 and 9 mm, and a commercial A4032-T6 alloy with a chemical composition of Table 1 was also V-bent for comparison.

Table 1 Chemical composition of the utilized commercial A4032-T6 alloy (mass%).

Si	Fe	Cu	Mg	Cr	Ni	Zn	Al
11.54	0.23	0.99	1.06	0.03	0.90	0.01	Bal.

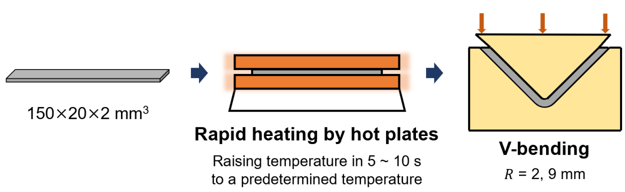

Fig.1 Procedure of hot stamping of Al-Si wrought alloys. V-bending was conducted at room temperature or after rapid heating to 350˚C maximum.

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3. Results and discussion

The results of tensile tests at room temperature showed that irrespective of Si content, ultimate tensile strength of the three Al-Si alloys reaches 200-210 MPa after 80% cold-rolling, although elongation to fracture decreases with increasing Si content. SEM microstructures suggested that the coarsened Si particles are deformed by cold rolling, and then the edges of broken Si particles act as starting points of crack generation, resulting in the earlier fracture of Al-7%Si and Al-12%Si alloys.

On the formability of the cold-rolled specimens, on the other hand, Al-3%Si and Al-7%Si alloys were both successfully V-bent at R = 9 mm, indicating that the amount of Si particles has less influence on the degradation of formability. However, V-bending of more Si particle containing Al-12%Si could not be accomplished at room temperature, and therefore rapid heating to 250°C became quite effective for improving the formability of Al-12%Si alloy as well as a commercial A4032-T6 alloy.

The effectiveness of such a hot stamping method was clarified even in the case of R = 2 mm; i.e. Al-3%Si alloy can be V-bent at room temperature, whereas rapid heating to 250, 300 and 350°C are needed for Al-7%Si, Al-12Si and A4032-T6 alloys, respectively. Therefore, it was revealed that higher Si content as well as some alloy elements (e.g. Cu and Mg) degrades the formability of Al-Si alloys, but rapid heating before hot stamping can improve the formability of recycled wrought aluminum.

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References

1) S. Kumai: Materials Transactions, 64 (2023), 319-333.