

Variation in Brazeability of Brazing Sheet by the Size of Si in Al-Si Filler Alloy Layer

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Abstract

In order to investigate the effect of silicon particle size in filler alloy of brazing sheet on brazeability of controlled atmosphere brazing, brazing sheets that had different silicon particle size were prepared by different casting methods. These brazing sheets were brazed. The temperature range at which molten filler flowed became lower in the brazing sheet that had fine and dense silicon particles. During brazing the filler alloy melted from the surroundings of silicon particles and the filler layer of the brazing sheet that contained fine and dense particles melted in a shorter time.

1. Introduction

Brazing sheet, aluminum alloy sheet that has Al-Si alloy layer on surface for brazing, is widely used for the heat exchangers of automobile. The reduction in thickness of brazing sheet is being targeted to decrease the weight of heat exchanger. Therefore brazeability is one of the important properties for brazing sheet because the layer of filler alloy becomes thinner and the total amount of filler becomes smaller.

The effects of alloy element and recrystallization behaviour of brazing sheet during brazing on brazeability have been investigated previously[1,2]. The silicon particle size in the Al-Si filler alloy layer is also thought to affect the brazeability. Woods[3] investigated the effect of silicon particle size on brazeability in dip brazing. However, since the heating rate of dip brazing process is rapid, the result may not be directly applicable to the Controlled Atmosphere Brazing (CAB) method that is currently used.

In this study two kind of casting methods were chosen for controlling silicon particle size in Al-Si filler alloy.

2. Experimental

Brazing sheets with filler alloy compositions of Al-11.5%Si and Al-7.5%Si alloy were prepared by twin roll casting and book mold casting. The chemical compositions of the filler alloys are shown in Table 1.

Figure 1 shows the production process for the experimental brazing sheet samples. The twin roll cast plates were cold rolled to 5mm in thickness and the book mold cast ingots were scalped and hot rolled to 5mm in thickness for cladding.

Table 1: Chemical compositions of filler alloy (mass%)

	Alloy	Si	Fe	Al
Twin roll	Al-11.5mass%Si	11.5	0.3	Bal.
	Al-7.5mass%Si	7.5	0.3	Bal.
Book mold	Al-11.5mass%Si	11.7	0.3	Bal.
	Al-7.5mass%Si	7.8	0.3	Bal.

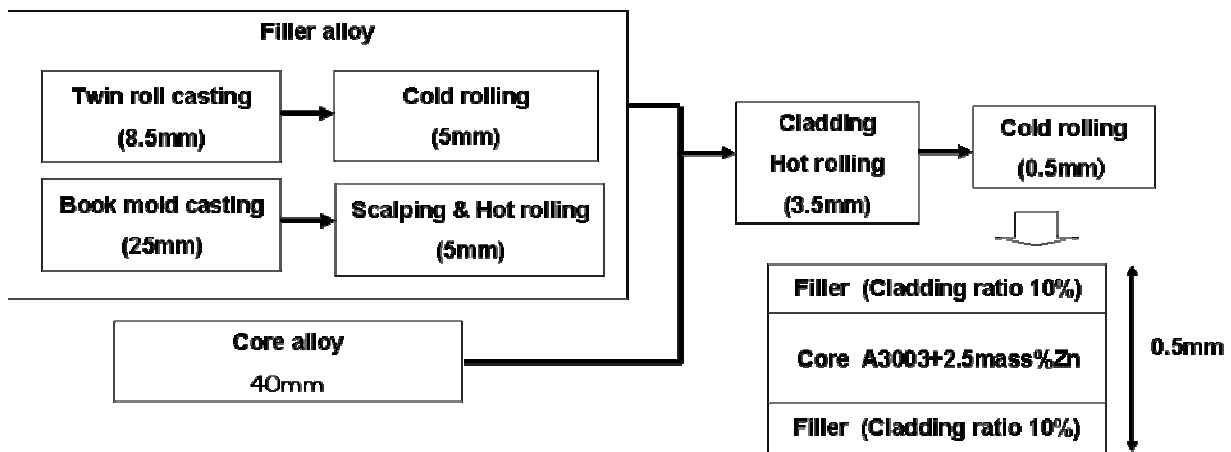


Figure 1: Schematic diagram of experimental production of brazing sheet.

A3003 alloy with 2.5wt.%Zn added was prepared for core alloy. The core was combined with filler alloy, hot clad rolled and cold rolled. The final thickness of brazing sheets was 0.5mm and cladding ratio of filler alloy was 10% on both sides. A flow factor was calculated after carrying out a drop test of brazing sheet so as to estimate brazeability. Figure 2 shows the method of determining the flow factor from the drop test. The CAB condition for drop test was at 600 degree C for 3 min.

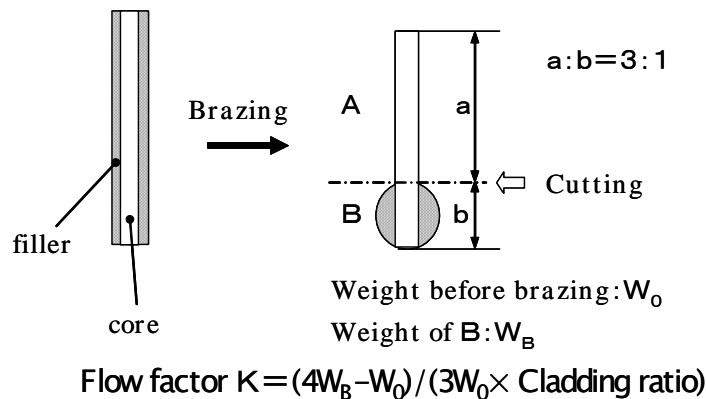


Figure 2: Testing method for flow factor : Drop test method.

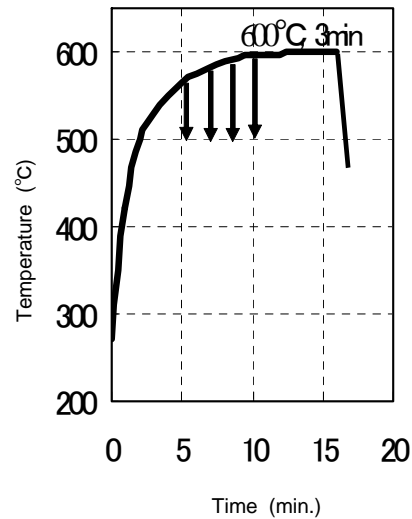
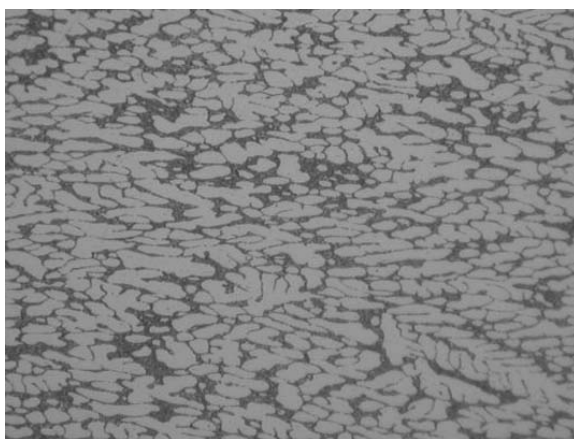


Figure 3: Heating pattern of brazing.

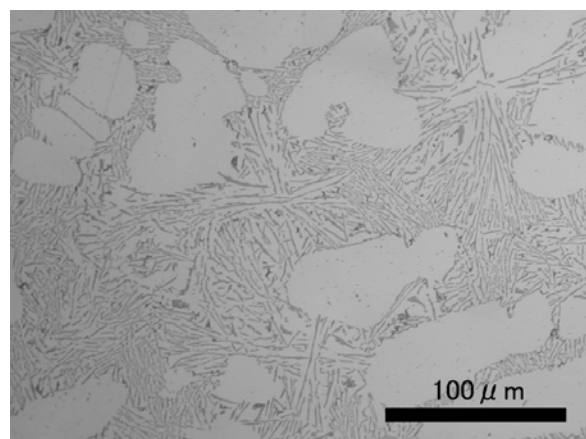
The heating pattern of the CAB brazing is shown in figure 3. During the tests, specimens were taken out at various times during the heating cycle to measure the change in flow factor during the brazing process.

3. Result and Discussion

The microstructures in the twin roll casting plate and the book mold ingot of Al-11.5mass%Si are shown in figure 4. The microstructure of twin roll cast sheet was fine because the cooling rate during solidification of twin roll casting was high. Figure 5 shows the microstructure of brazing sheet where the upper part of the images is the filler alloy layer. The Si particle size in the twin roll cast alloy was less than 1 micron and in the book mold cast alloy it was between 2 and 10 microns.

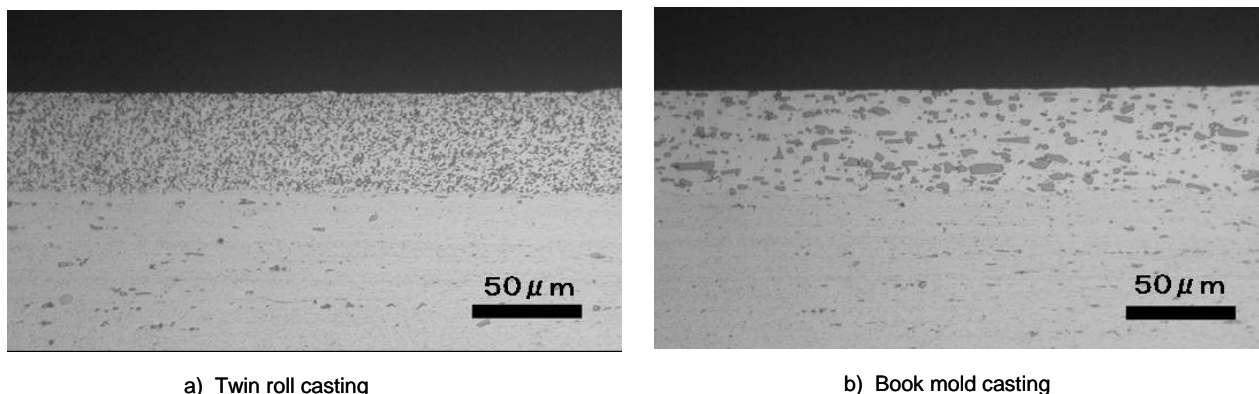


a) Twin roll casting



b) Book mold casting

Figure 4: Micro structure of as cast Al-11.5mass%Si filler alloy.



a) Twin roll casting

b) Book mold casting

Figure 5: Micro structure of Al-11.5mass%Si filler alloy layer in brazing sheet.

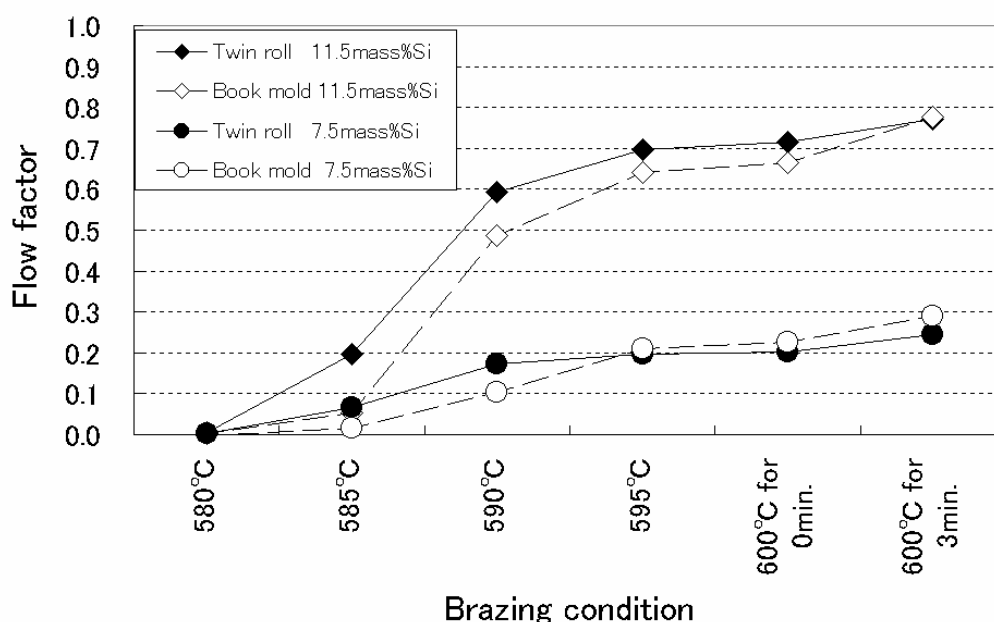


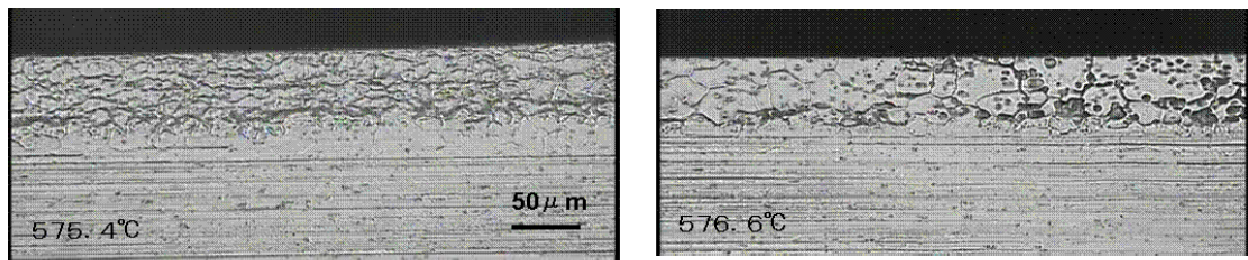
Figure 6: Variation in flow during brazing heating.

The results of the drop tests of such brazing sheets are shown in figure 6. The horizontal axis indicates heating condition during brazing process on the way to 600 degree C for 3min. With passage of the brazing process the flow of filler progressed as follows: flow of brazing sheets was not observed at 580°C; flow increased significantly between 585 ° C and 595 ° C. This temperature range is higher than eutectic temperature of Al-Si alloy. However, these flow factor measurements were made during the brazing heating cycle, as indicated in Figure 3 and, hence, do not reflect the equilibrium state for the intermediate temperatures.

In comparing between the different brazing sheets, it is seen that the flow factor differed according to the amount of silicon at any casting condition of the filler alloy. Flow of filler increased with the higher amount of silicon in Al-Si alloy. This is because 11.5mass% silicon is near eutectic composition and 7.5mass% silicon is hypoeutectic composition: hence the amount of liquid varies according to the amount of silicon. The effect of silicon particle size for each of the two alloys is shown by the different filler flow behaviour in the temperature range from 585 °C to 595 ° C.

The temperature range at which molten filler flowed was lower for the twin roll cast brazing sheet that had fine and dense silicon particles than that for the book mold cast sheet with

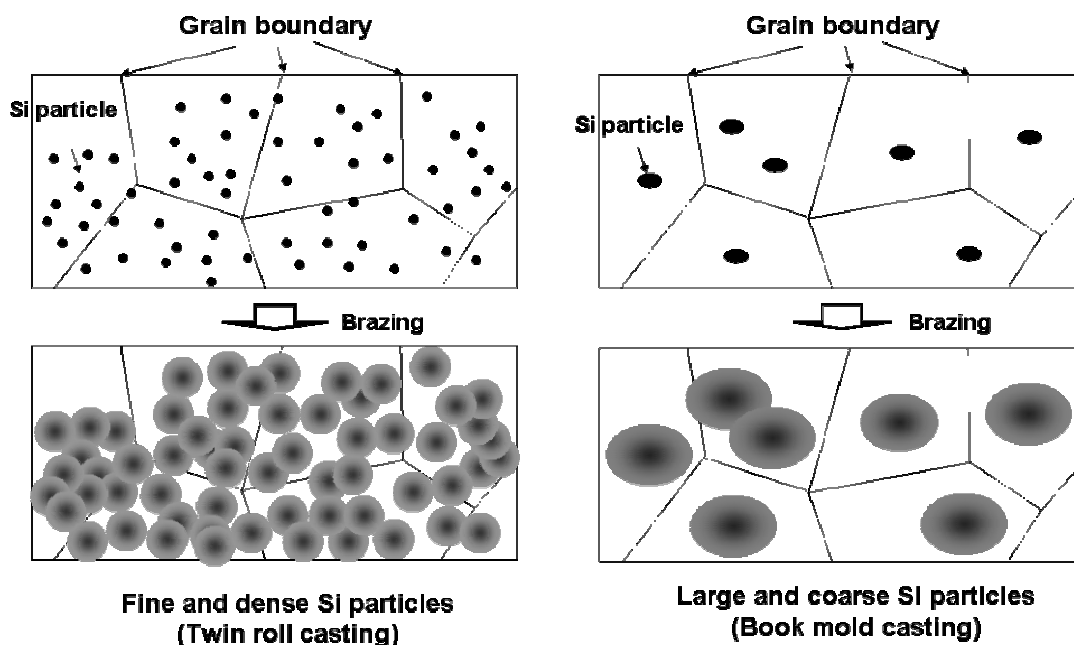
large and coarse silicon particles.. However, the amount of flowed filler did not change according to silicon particle size after finishing CAB at 600 degree C for 3 minutes.



**Fine and dense Si particles
(Twin roll casting)**

**Large and coarse Si particles
(Book mold casting)**

Figure 7: Micro structures of brazing sheet by direct observation during heating. Filler alloys are Al-11.5mass%Si.



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Figure 8: Schematic figure of filler alloy during melting.

A optical microscope which had a heating device was used for direct observation of micro structure in filler alloy layer during heating and melting of the filler layer. Figure 7 shows the microstructure immediately after emergence of liquid from filler alloy layer. The filler layer made by twin roll casting appeared to melt uniformly

These results are schematically shown in figure 8. During brazing heating the filler alloy starts melting from the surroundings of silicon particle. Therefore filler layer in the brazing sheet that has fine and dense particles melts in a short time. On the other hand, when the silicon particles are large and coarse, it takes some time to extend liquid region from surroundings of silicon particle to all over the filler layer. This is considered to be the reason the temperature range at which molten filler flowed varied according to the size of silicon particle.

4. Conclusions

Silicon particle size in filler alloy of brazing sheet was varied by different casting methods. The Flow factor of the brazing sheets was investigated. After finishing CAB at 600 degree C for 3 minutes the amount of flowed filler changed according to silicon content of Al-Si filler alloy but not to silicon particle size. Flow of filler during brazing process varied according to silicon particle size. The temperature range at which molten filler flowed become lower in the brazing sheet that had fine and dense silicon particles by twin roll casting.

References

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