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Solidification Manner of Overlay Alloy in Al-Mn/Al-Si Alloy Clad Strips Produced by Vertical-Type Tandem Twin-Roll Casting

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Three Al-Si alloys with different Si compositions, 10 %Si, 12.6 %Si, 14 %Si were provided as the overlay alloy to clad the A3003 base strip by vertical-type tandem twin-roll casting. The influence of the Si composition on the overlay solidification manner and the bonding condition of interface were investigated. Regardless Si composition, the microstructure of overlay surface region exhibited fine eutectic structure, and the mid-thickness region of overlay consisted of α-Al dendrites and eutectic structure. Globular α-Al grain structure was also observed near the base/overlay interface region for 10 %Si. No un-bonded area was observed for 10 %Si. In contrast, a limited number of local un-bonded areas were observed at the interface for 12.6 %Si and 14 %Si. Bonding condition at the base/overlay interface depended on the growth manner of solidifying shell and the location where solidification finished. For 10%Si, the final solidification area was located at the boundary of growth front of solidifying shell and the globular grain band.

Keywords: *twin roll casting, clad strip, interface*

1. Introduction

Clad plates are widely used for both structural and functional material applications. However, the fabrication process of the clad sheets, such as hot-roll bonding, is complicated and involves the expenditure of a large amount of time and energy. In order to solve this problem, the present authors have developed a vertical-type tandem twin-roll casting method[1], which can produce the clad strips from molten metal directly by single step. This provides great time- and energy saving effects. The caster consists of two or three twin-roll casters arranged vertically. The base strip is produced by the upper caster and introduced to the roll gap of lower caster. When the base strip passes through the roll gap of lower caster, the overlay alloy melt is poured to the roll gap. The solidification of overlay strip alloy takes place and the clad strip is produced. In the previous studies, A4045/A3003 /A4045 clad strips, for automobile heat exchanger were produced by the present method and processed to the clad sheets[2]. The microstructure and mechanical properties were compared to those of the clad sheets fabricated by the conventional hot-rolling process. Twin-roll cast products exhibited refined microstructure and the improved mechanical properties than the hot-roll bonded products. Hypo-eutectic Al-Si alloys A4045 (Al-10 %Si) are generally used for the overlay strip of brazing sheets. This is partly because the hot-roll bonding is not suitable for the eutectic and hyper-eutectic Al-Si alloys due to the occurrence of fracture and de-bonding of Si particles during the repeated rolling process. In contrast, the present method is free from such a restriction. Therefore, in the present study, three Al-Si alloys with different Si compositions were provided as the overlay alloy to clad the A3003 base strip. The influence of the Si composition on the overlay solidification manner and the bonding condition of base/overlay interface was investigated.

2. Experimental procedure

2.1 Sample materials

Three layer clad strip was fabricated by vertical-type tandem twin-roll caster. Sample materials are the 3003 aluminium alloy (Al-1 %Mn) for the base strip and Al-10 %Si (corresponding to A4045), Al-12.6 %Si (Al-Si eutectic composition), and Al-14 %Si alloy for the overlay strip.

2.2 Vertical-type tandem twin-roll casting

Casting condition on the vertical-type tandem twin-roll casting is as follow. Solidification length of the upper and lower caster are 60 and 80 mm, respectively. Roll separating force are 2.2 and 4.4 kN. Roll rotating speed is 40 m/min. Casting temperature of molten metal is 15 ℃ higher than each liquidus temperature. In addtion, 50 ℃ higher pouring temperature experiment was also carried out to consider the effect of pouring temperature.

2.3 Microstructure observation

Optical microscopic observation was carried out. The polished cross-section was etched by Weck's reagent (4 g $KMnO_4$, 1 g NaOH, and 100 mL distilled water). SEM-SEI observation was also conducted.

3. Result and discussion

3.1 Microstructure of overlay strip

Regardless the Si composition, the microstructure of the overlay surface region exhibited fine eutectic structure, and the mid-thickness region of overlay consisted of α-Al dendrites and eutectic structure. Especially for 14 %Si, the microstructure was the mixture of dendrites and eutectic structure through the thickness. In contrast, in the case of 10 %Si, there were a large amount of globular grains near the base/overlay interface. The reason of this segregated globular grain is considered as follows. The growth front of overlay solidifying shell on the roll surface is a mushy layer consisting of dendrite branches and liquid phase. Then, the fragmentation of dendrite tip in the mushy layer occurs by melt convection. These fragments grow into the globular grains[3]. Eventually, these grains gather in the interface and forms a globular grain band.

3.2 Base/overlay strip interface

No un-bonded area was observed at base/overlay interface for 10 %Si. In contrast, a limited number of local un-bonded areas observed at the interface for 12.6 and 14 %Si (Fig. 1). In the case of both 12.6 and 14 %Si overlay strips, the defect such as solidification shrinkage and gas porosity was formed at the base/overlay interface, it is considered that overlay solidification took place from the roll surface and the growth front developed toward the base strip, finally overlay solidification finished at the interface.

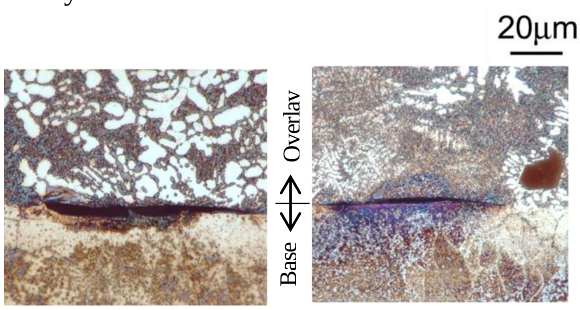

Fig. 1 Un-bonded zone of interface (12.6 %Si, 14 %Si)

3.3 Final solidification area for 10 %Si overlay

To examine the final solidification area for 10 %Si overlay strip, the experiment was conducted of 50 ℃ higher pouring temperature. Relatively higher pouring temperature can lead increasing of solidification defects. Left side of Fig. 2 shows overlay microstructure observed by OM. Continuous internal crack (black line) was observed at boundary area of overlay solidifying shell and globular grain band. Right side of Fig. 2 is SEM-SEI image of internal crack surface. Dendrite tips were observed and it indicates this internal crack was induced by high pouring temperature. Thus, it is investigated that the solidification finished at around this area, boundary of solidifying shell and globular grain band for 10 %Si overlay. Therefore, the defects were not observed at the base/overlay interface in the case of 10 %Si.

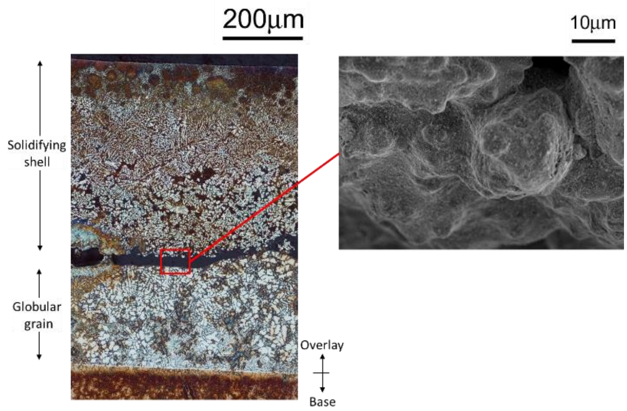

Fig. 2 OM image of 50 ℃ higher pouring temperature overlay microsturcure and SEM image of defect

4. Conclusion

Solidification manner was investigated for several Si composition overlay strip for 3 layer clad strips produced by vertical-type tandem twin-roll casting. For 10 %Si overlay strip, the overlay solidification finished at the boundary area of solidifying shell growth from roll surface and globular grain band. Local un-bonded areas were observed at the base/overlay interface for 12.6 and 14 %Si overlay strips. This indicates the overlay solidification finished at the base/overlay interface for 12.6 and 14 %Si. These microstructure difference in the final solidification area is considered to be due to the difference of solidification manner depending on the Si composition.

References

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