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CASTING OF CLAD STRIP BY A TWIN ROLL CASTER

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Abstract

A vertical type tandem twin roll caster and a vertical type twin roll caster equipped with a scraper were proposed to cast clad strip. The vertical type tandem twin roll caster can cast a three or five - layer clad strip, and the vertical type twin roll caster equipped with a scraper can cast two - layer clad strip. In this paper, the casting parameters that affect the clad ratio, bonding of the strips and re-melting of the layers are investigated.

Introduction

The conventional fabrication of a clad strip requires many processes and much energy. The strip is made from a slab by surface scraping, heat treatment, hot rolling and cold rolling. The strips are cleaned, the edges of the strips are welded, and the strips are connected by hot rolling. Recently, "Fusion Tecnology" has been developed that produces clad material by direct chill (DC) casting [1,2]. If the strip could be made directly from the molten metal, energy would be saved. A roll caster can cast the strip directly from the molten metal, and the development of a twin type roll caster that can cast clad strips is one solutions for reducing the energy needed to make clad strips. However, only a few reports describe the roll casting of clad strip [3,4], and one of these reports used a vertical type twin roll caster. Therefore, two kinds of laboratory size twin roll casters were desigened and assembled in this study. One is a vertical type tandem twin roll caster and the other is a vertical type twin roll caster equipped with a scraper. The vertical type twin roll caster has some advantages. For example, the vertical type twin roll caster is suitable for high speed roll casting, and allows easy pouring of the molten metal.

A vertical type tandem twin roll caster

A schematic illustration of a vertical type tandem twin roll caster (VTTRC) for three-layer clad strip is shown in Figure 1. A photograph and schematic illustration of the VTTRC for five-layer clad strips are shown in Figure 2. In Figure 1, a base strip is cast by the upper twin roll caster and overlay strips are cast by the lower twin roll caster. The thicknesses of the base strip and the overly strips are controlled by the solidification length. The melting point of the alloy of the base strip must be higher than that of the overlay strips.

A vertical type twin roll caster equipped with a scraper

A schematic illustration of a vertical type twin roll caster equipped with a scraper (VTRCS) is shown in Figure 3. Due to the scraper, the base strip contacts the molten metal of the overlay strip without contacting to the atmosphere. The scraper prevents the mixture of the molten metals of the base strip and the overlay strip.

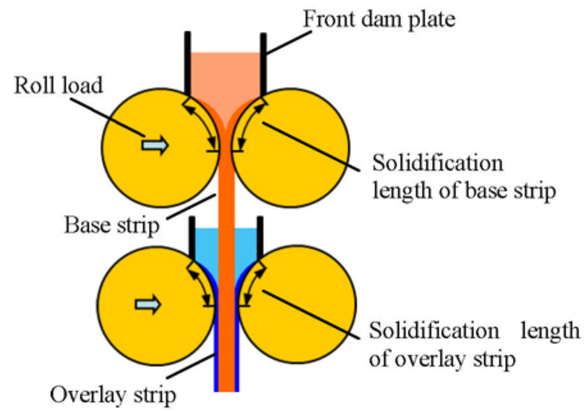


Figure 1. Schematic illustration of a vertical type tandem twin roll caster

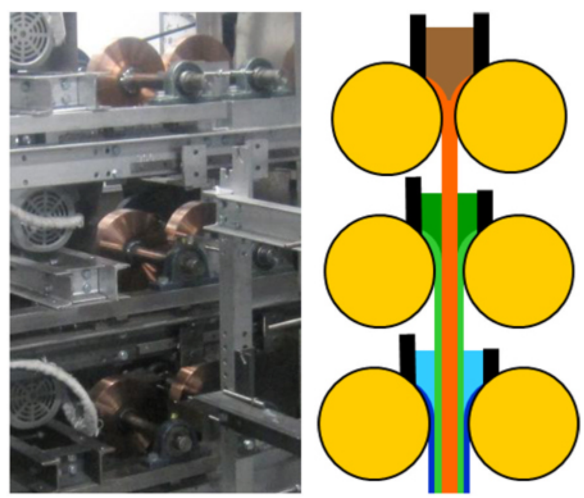


Figure 2. Photograph of a vertical type tandem twin roll caster

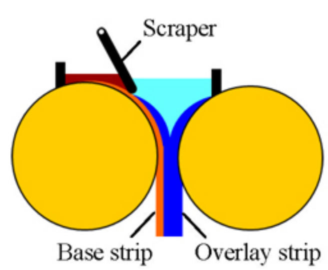


Figure 3. Schematic illustration of a vertical type tandem twin roll caster

Clad strips cast by the VTTRC

Control of clad ratio

The thicknesses of the base and the overlay strip are controlled by the solidification length. The relationship between the solidification length, strip thickness and clad ratio is shown in Table 1. Cross-sections of as-cast clad strips cast under the casting conditions of Table 1 are shown in Figure 4

Table 1. Casting conditions and clad ratios

Solidification length, strip thickness, clad ratio	(a)	(b)
Material of base strip	3003	3003
Material of overlay strip	4045	4045
Casring temperature of 3003 (°C)	670	670
Casting temperature of 4045 (°C)	610	610
Solidification length of base strip (mm)	60	120
Solidification length of overlay strip (mm)	80	25
Thickness of base strip (mm)	3.0	4.5
Thickness of base strip (mm)	1.3	0.5
Clad ratio	2.5	8.9
Roll speed (m/min)	30	30

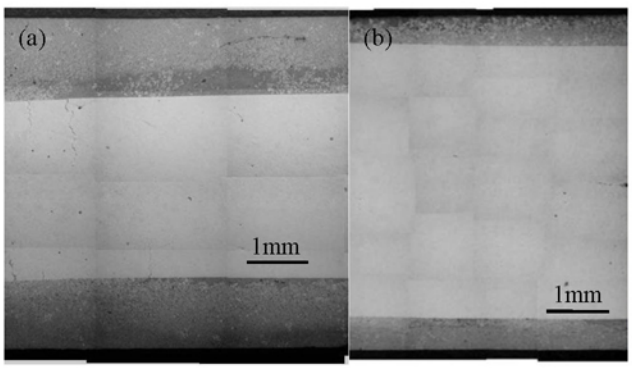


Figure 4. Cross sectionss of clad strips of different clad ratios

Effect of casting conditions of overlay strip on clad strip

Overlay strip 4045 could be bonded to the base strip 3003 at roll loads of 0.5, 4.4 and 8.8 kN. The roll load was cont rolled by springs. The cross sections around the intefaces are shown in Figure 5. The base strip and the overlay strip were bonded without a gap by the small roll load.

The effect of the melt temperature of the lower caster on the interface between the base strip (3003) and the overlay strip (4045) is shown in Figure 6. The solidus line temperature and the liquidus line temperature of 3003 are 643℃ and 653℃, respectively. The pouring temperatures 610℃ and 630℃ of 4045 arre lower than the solidus line temperature of 3003. Therefore, 3003 was not melted by the heat from 4045, and so 4045was bonded to 3003. It is estimated that the melting of the base strip was not an essential condition to realize bonding. The pouring temperature 700℃ of 4045 was higher than the liquidus line temperature. The interface between 3003 and 4045 is clear as shown in Figure 6(c). It is estimated that 3003 was not melted by the heat from the 4045, and the temperature of 3003 did not increase up to the liquidus line temperature.

Figure 7 shows the cross section of the clad strip. The base strip is 4045 and the overlay strips are 3003. The 4045 strip was melted by the 3003strip. This means that the solidification temperature of the base strip must higher than that of the overlay strip to cast sound clad strip.

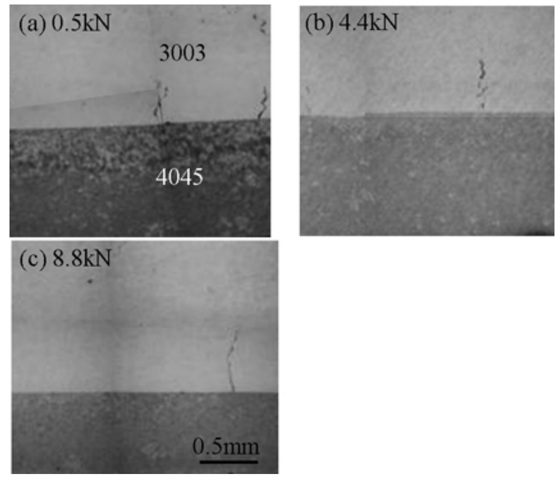


Figure 5. Effect of the roll load of the lower caster on the interface between the base strip (3003) and overlay strip (4045). Roll speed was 40m/min. Melt temperature of the 3003 and 4045 were 670°C and 610°C, respectively. Roll load of the upper caster was 2.2kN.

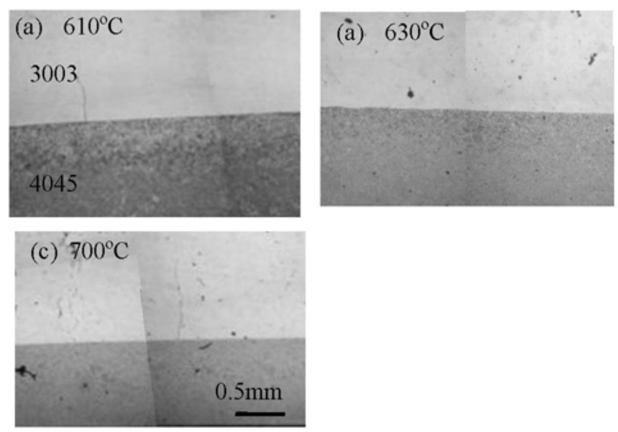


Figure 6. Effect of melt temperature of the lower caster on the interface between the base strip (3003) and overlay strip (4045). Roll speed was 40m/min. Roll load of the upper caster and lower caster were 2.2kNand 1.1kN, respectively. Melt temperature of the base strip was 670°C.

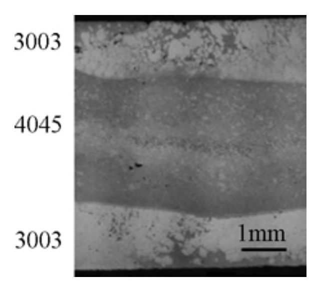


Figure 7. Cross section of clad strip. Base strip is 4045 and overlay strips are 3003.

Casting of overlay strips from different alloys

Clad strips for overlay strips having different solidification temperatures were cast. The solidification temperatures and the pouring temperatures of the alloys for the overlay strips are shown in Table 2. The combinations of alloys for the overlay strips and their solidification lengths are shown in Table 3. The roll speed was 30 m/min, and the roll load was 4.4 kN. The surfaces of the overlay strips are shown in Figure 8. The surface of the overlay strip having a lower solidification temperature than that of the other alloy melted as shown in Figure 8 No.3 and No.4. It is estimated that the surfaces were melted by the heat from the overlay strips having the higher solidification temperatutes.

Table 2 Solidification temperatures and pouring temperatures

Alloys	Solidification temperature (^{O}C)	Pouring temperature (^{O}C)
Alloy 1	575-590	700
Alloy 2	577-620	700
Alloy 3	617-637	700
Alloy 4	627-643	700
3003 (base strip)	643-654	700

Table 3 Combinations of alloys and solidification length

Conditions	Overlay strip A	Overlay strip B	Solidification length of Overlay strip (mm)
No.1	Alloy1	Alloy1	25
No.2	Alloy1	Alloy2	25
No.3	Alloy1	Alloy3	25
No.4	Alloy1	Alloy4	25
No.3-Long	Alloy1	Alloy3	70
No.4-Long	Alloy1	Alloy4	70

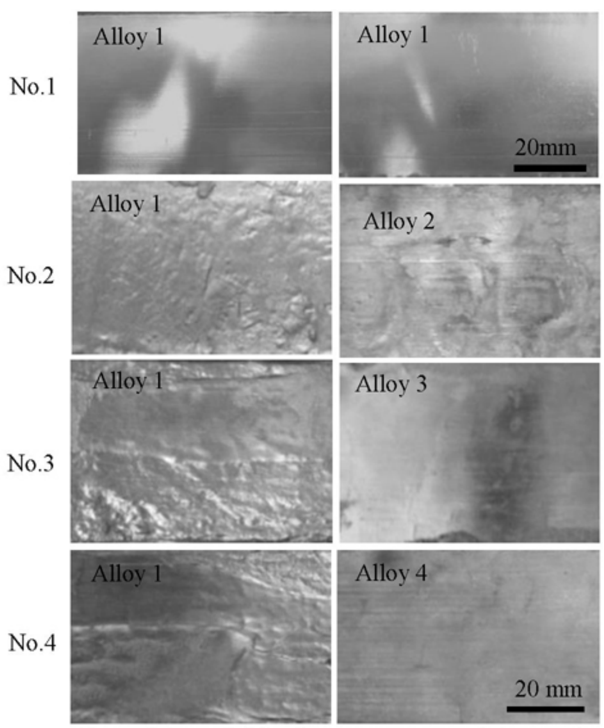


Figure 8. Effect of the solidification temperature of the overlay strips on the surface of the overlay strip. Casting conditions are shown in Table 2 and Table 3. Solidification length was 25mm.

The surface of the overlay strip having a solidification temperature lower than that of the other alloy was not melted under the condition that the solidification length was 70 mm, as shown in Figure 9. The temperature of the strip decreases as the solidification length becomes longer. Therefore, the overlay strip having a solidification temperature lower than that of the other alloy did not melt.

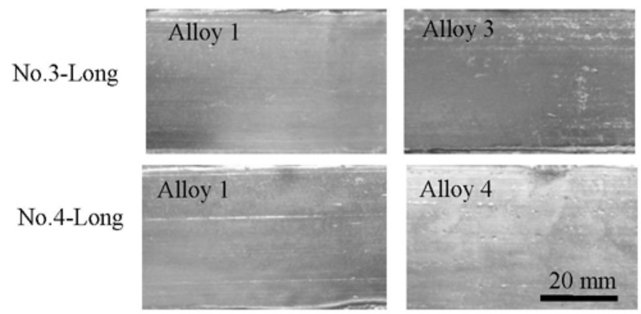


Figure 9. Effect of the solidification temperature of the overlay strips on the surface of the overlay strip. Casting conditions are shown in Table 2 and Table 3. Solidification length was 70mm.

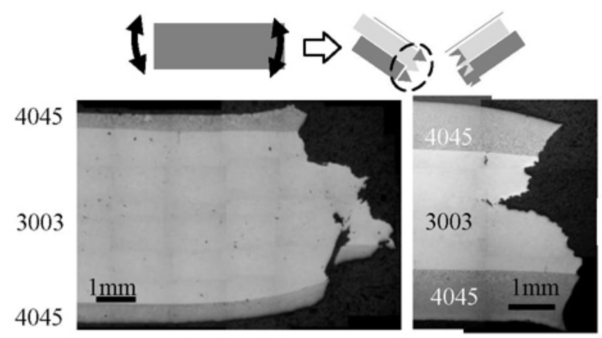
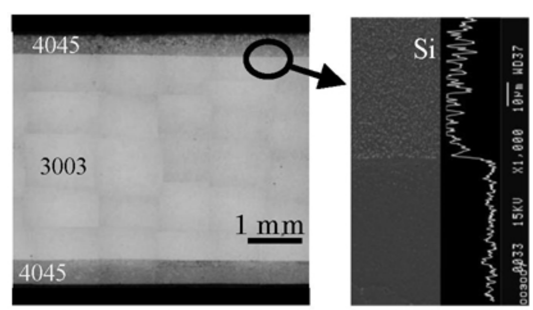
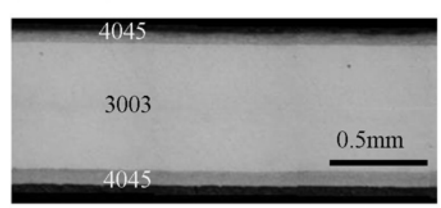


Figure 10. Continuous bending test to estimate bonding condition



(a) line analysis at the interface of as-cast clad strip



(b) cross section of cold roll clad strip

Figure 11. Result of the line analysis around the interface and the coross section of the cold rolled clad strip

Properties of the three layers clad strip

The bonding condition between the base strip and the overlay strip was easily investigated by continuous bending until breaking. A broken cross-section is shown in Figure 10. As shown, the strips were strongly bonded at the interfaces, and so the overlay strips did not peel from the base strip. The thickness of the overlay strip did not influence on the bonding condition in Figure 10.
A line analysis was conducted at the interface between the base strip and an overlay strip. The resut is shown in Figure 11(a). Si, which is an element of 4045, is not found in 3003. That is, Si did not diffuse from 4045 to 3003. It is thought that the 3003 base strip was not melted by the heat from the 4045 overlay strip. Thus, cold rolling could be conducted on the as-cast clad strip without peeling of the strips at the interface. The cross-section of cast and cold rolled clad strip is shown in Figure 11(b). The clad ratio of the clad strip was not changed by the cold rolling.

Five layers clad strip

Figure 12 shows the cross-section of five-lyer clad strip cast from three kinds of aluminum alloys by the VTTRC shown in Figure 2. The aluminum alloy having a higher solidification temperature was cast by the upper twin roll caster. The aluminum alloy having the lowest solidification temperature was cast as the outmost layers. The five layers were strongly bonded. The inner strips were not melted by the heat from the outer strips. The interfaces between the strips were clear.

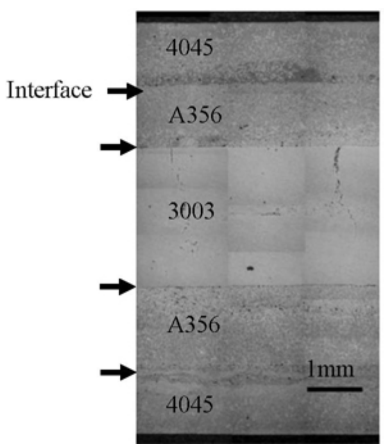
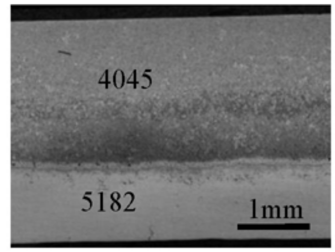


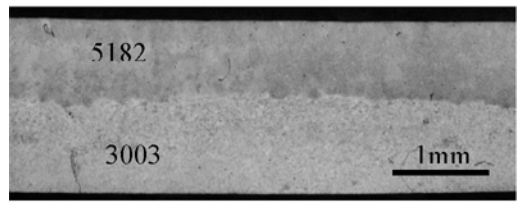
Figure 12. Cross section of as-cast five layers clad strip cast by the VTTRC shown in Figure 2

Clad strips cast by the VTRCS

Figure 13 shows cross-sections of the clad strips cast by the VTRCS shown in Figure 3. The roll speed was 30 m/min. Casting clad strip consisting of Al-Mg strip is not easy on the VTTRC. The Al-Mg alloy strip does not contact other strips, or gaps occur at the interfaces. One of the popular Al-Mg alloys is 5182. The 5182 strip could be bonded to 4045 strip and 3003 strip. The solidification temperature of 4045 is lower than that of 5182, and the solidification temperature of 3003 is higher than that of 4045. The clad strip could be cast at both combinations of solidification temperatures. The 5182 strip was strongly bonded to the 4045 and 3003strips. The strips were bonded without contacting to the oxidizing atomosphere. Therefore, the bonding was not influenced by oxidation.



(a) 5182 strip was scribed



(b) 3003 strip was scribed

Figure 13. Cross section of the clad strips cast by the VTRCS

Conclusions

A vertical type tandem twin roll caster was proposed to cast three-layer and five-layer clad strip. A vertical type twin roll catster equipped with a scraper was proposed to cast two layers clad strip. The clad strips cast by the twin roll casters had clear interfaces, and element strips were strongly bonded. The solidification temperature is a foctor in the melting of the base strip and the overlay strips. The solidification temperature of the base strip must be higher than that of the overlay strips to cast sound clad strip. When the solidification temperatures of the overlay strips are different, longer solidification length of the overlay strips is better to prevent melting of an overlay strip having alower solidification.

Reference

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