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Casting of Three Layers of Aluminum Alloy Clad Strip Using a Different Diameter Twin Roll Caster

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Casting of three layers of aluminum alloy clad strip was tried using a different diameter twin roll caster. This caster was equipped with a lower roll of 1500mm in diameter and an upper roll of 250mm in diameter, and the width of these rolls was 50mm. The surfaces of the first and the third layer, which contacted to the second layer, were dragged at the condition of solid or semisolid using a scraper from molten metal by rotation of roll. The second layer was solidified between the first and the third layer, and connected with the first and the third layer. In this study, the first layer and the third layer were Al-Mn alloy, and the second layer was Al-Si alloy. The three layers of clad strip could be cast directly from the molten metal by one process using one caster. The component of three layers clad strip could be connected easily by very small force, for example, 18N/mm (per unit width). The clad strip did not peel off at the interface after bending until broken. The as-cast strip could be cold-rolled down to 1mm after annealing without peeling at interface. In this way, the three layers of the clad strip were connected strongly. The interfaces were clear and Si of the second layer did not diffuse into the first and the third layer.

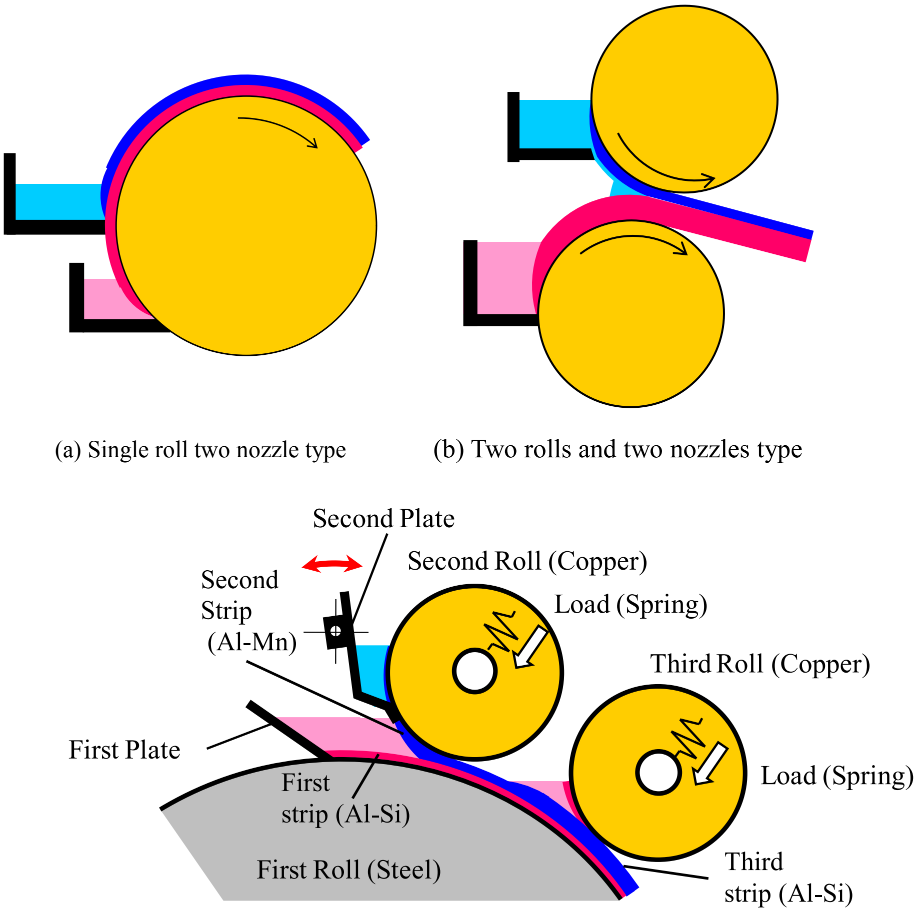
Keywords: *twin roll caster, roll casting, three layers clad strip, composite*

1. Introduction

The conventional manufacturing process of the aluminum alloy clad strip requires many processes. The aluminum alloy strip of component of clad strip was manufacturing respectively. The slab of aluminum alloy is cast by D.C. (Direct Chill) casting. The aluminum alloy strip usually made from slab by scraping, homogenization, hot rollings and cold rollings. The strips are connected after cleaning by hot rolling[1]. The conventional manufacturing process of the aluminum alloy clad strip requires much energy, and therefore CO_2 emission increases[2]. Recently, from the global environmental problem, CO_2 emission must be reduced. Therefore, process of manufacturing the clad strip which can save coast and energy is demanded. In this study, the different diameter twin roll caster for cast three layers of aluminum alloy clad strip was manufactured. This caster can cast make three layers clad strip of aluminum alloy from molten metal directly.

2. Roll casters to cast the clad strip

Figure 1 shows the schematic illustrations of a single roll caster and twin roll casters to cast the clad strip[3-5]. The basic process is (a), and this process is melt drag process. This process is difficult to manufacture of multi layers clad strip. Because, it is difficult to adjust of clearance of between the the nozzle and roll against solidification layer. In the process of (b), both of the upper and lower surface are solidified by rolls, and surfaces were flat. To connect the upper strip and lower strip, the surface of clad strip must be semisolid. The caster of (c) can cast three layers clad strip in which the liquidus temperature of the first and the third layer is lower than the second layer. However this caster can not make the three layers clad strip in which, the liquidus temperature of the first and the third layers are higher than that of the second layer. When the roll caster of (c) is used to cast three layers clad strip in which the liquidus temperature of the first and the third layer is higher than that of the second layer, the second strip is remelted by the third layer molten metal. The two rolls and two nozzles type caster which is shown in Fig.2 was invented to solve this problem in this study. When the caster of Fig.2 is used to cast three layers clad strip in which the liquidus temperature of the first and the third layer is higher than that of the second layer, the first and the third layers was solidified by rolls. The molten metal of the second layer heated the first and the third layers to connect three strip. The first and third layers are not remelted by the molten metal of the second layer, because the liquidus temperature of the second layer is lower than the solidus temperature of the first and third layer.



(a) Single roll two nozzle type (b) Two rolls and two nozzles type

(c) Different diameter roll caster to cast the clad strip

Fig.1 Roll caster to cast the clad strip

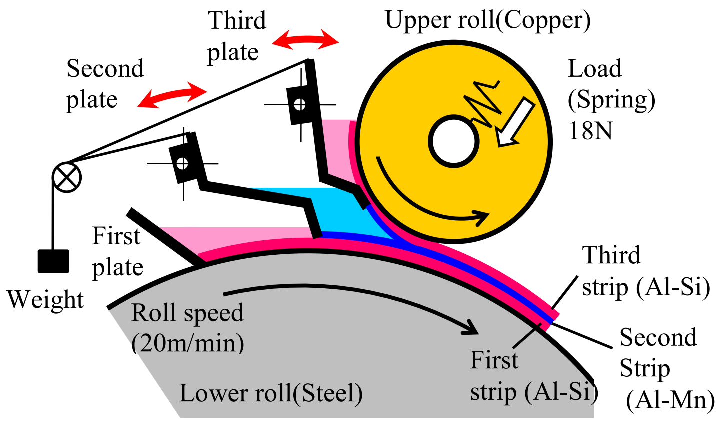


Fig.2 Experimental apparatus

3. A different diameter twin roll caster

Figure 2 shows the schematic illustrations of a different diameter twin roll caster. This caster was equipped with a lower roll of 1500mm in diameter and an upper roll of 250mm in diameter, and the width of these rolls was 50mm. The second and the third plate is suported by the fulcrum and they were depending on the thickness of the solidification layer of the first and the third layer as shown in Fig.3. This mechanical was available to prevent the molten metals from mixture. The molten metal of the second layer was poured between solidification layer of the first and the third layers. The molten metal of the second layer heated the first and the third layers to connect three layers. The second layer was solidified by the first and the third layers. The three layers were connected at the roll bite between the upper roll and the lower roll.

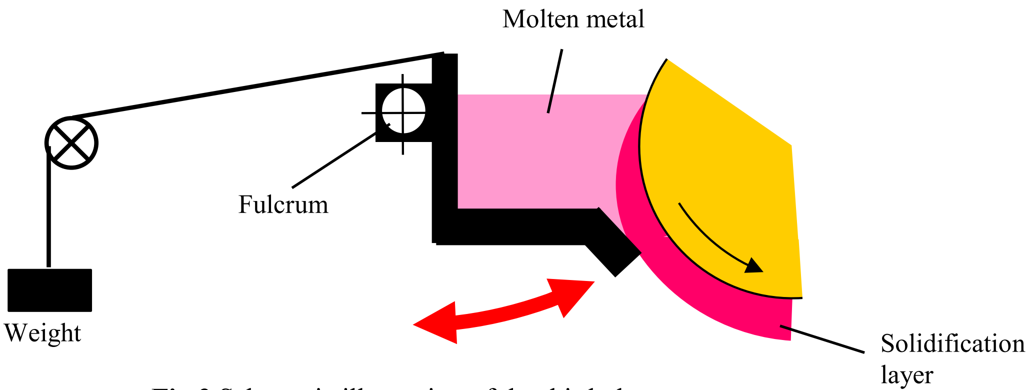
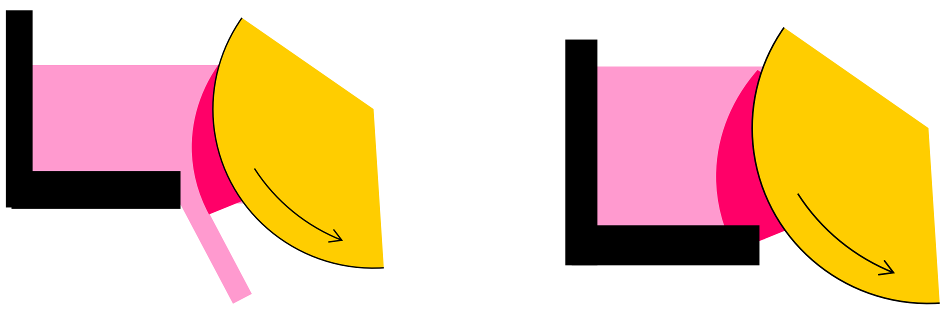


Fig.3 Schematic illustration of the third plate

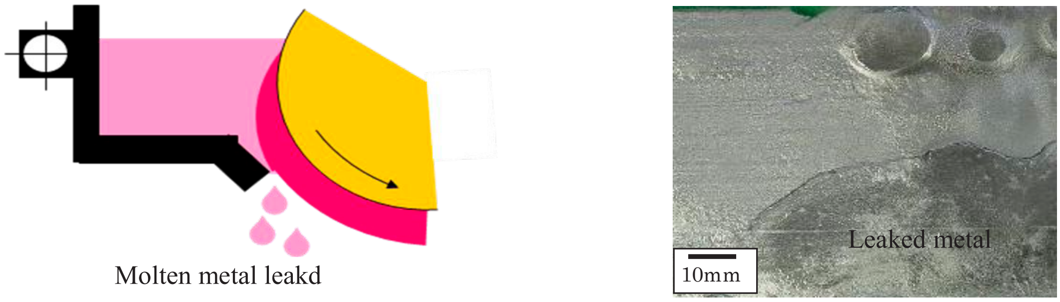
4. Dragging of the solidification layer using movable plate

In the different diameter twin roll caster in this study, the second plate was movable around the fulcrum. Only solidification layer could be dragged by the roll using the movable plate. When a fixed plate was used, the molten metal leaked from the gap between the solidification layer and the plate as shown in Fig.4 (a), because the thickness of the solidification layer was not constant. In other instance, solidification layer stuck at the gap between the roll and the plate as shown in Fig.4 (b). Therefore, the plate modified to movable one which rotated around the fulcrum freely. When the movable plate made from mild steel was used, a leak of the molten metal occurred as shown in Fig.5 (a). The strip surface cast at leak condition (Fig.5 (a)) is shown in Fig.5 (b). Dragging of only the solidified layer was required. The insulator paper was attached the plate made from mild steel to prevent the leaking as shown in Fig.6 (a). The insulator paper was full the clearance between the solidification layer and the plate and the leak of molten metal was prevented. The surface of cast strip using a movable plate with insulator paper was shown in Fig.6 (b). The plate with slope was used to cast the third layer as it was useful to prevent the leak. However, the first layer easily stuck at the plate as shown in Fig.7 (a). Therefore, the plate without slope was used to cast the first layer as shown in Fig.7 (b).



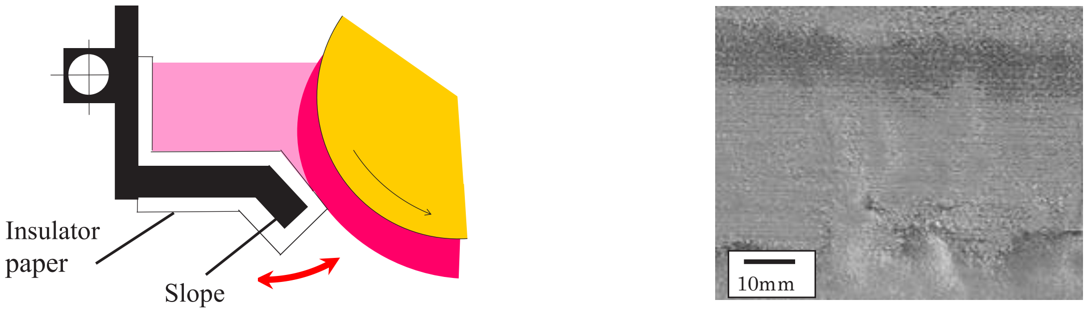
(a) Molten metal leak from the gap (b) Solidification layer stuck at the gap

Fig.4 Schematic illustration showing the unsoundness of the fixed plate



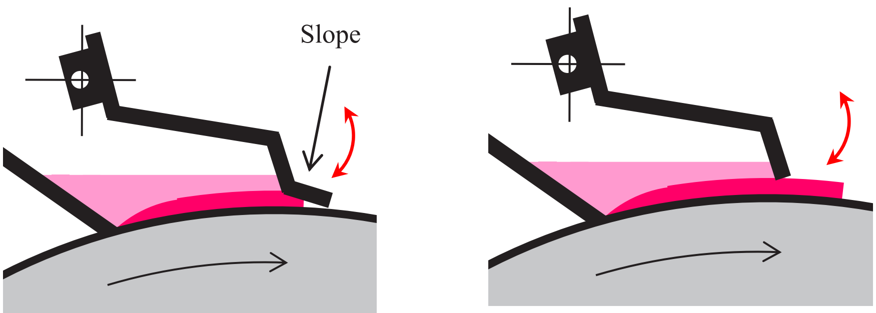
(a) The movable plate made from mild steel (b) The surface of leaked metal

Fig.5 When used the movable plate made from mild steel



(a) The movable plate made from mild steel with insulator paper (b) Not trace of leaked metal

Fig.6 When used the movable plate made from mild steel with insulator paper



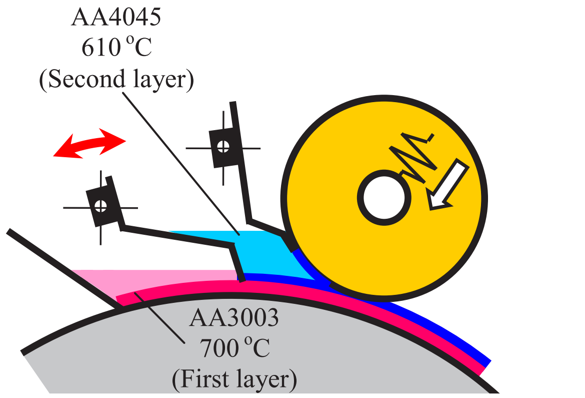
(a) Movable plate with slope (b) Movable plate without slope

Fig.7 Effect of the slope of the first plate

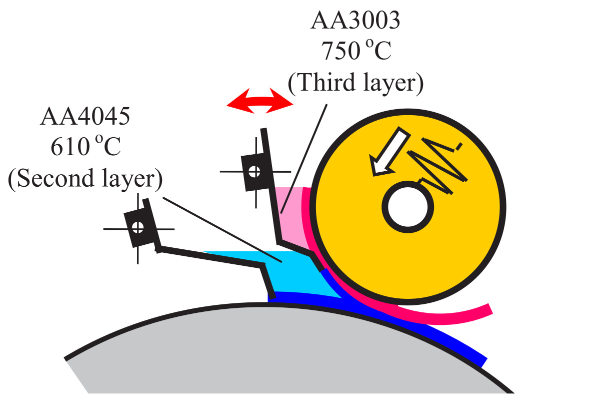
5. Effect of material of rolls for connecting conditions of the clad strip

In this study, the molten metal of the second layer heated the first and the third layer up to the temperature suitable for connecting. The material of the upper roll was different from that of lower roll at the roll caster in this study. The upper roll was made from copper, and the lower roll was made from mild steel. Two kind of clad strips were cast to investigate the effect of the thermal conductivity of the roll material. One was assembled from the first layer (AA3003) and the second layer (AA4045) by roll caster of Fig.8 (a). In Fig.8 (a) the melt temperature of the first layer (AA3003) was 700 ^{o}C, the melt temperature of the second layer (AA4045) was 610 ^{o}C. When AA3003 was cast as the first layer by the mild steel roll, two layers clad strip could be connected as shown in Fig.9 (a). The other was assembled from the second layer (AA4045) and the third layer (AA3003) by roll caster of Fig.8 (b). In Fig.8 (b) the melt temperature of the second layer (AA4045) was 610 ^{o}C, and melt temperature of the third layer (AA3003) was 750 ^{o}C. When AA3003 was cast as the third layer by the copper roll, two layers clad strip could not be connected as shown in Fig.9 (b). The connecting became easy as the melting temperature of AA3003 become higher. Therefore condition of Fig.8 (b) was suitable at the point of connecting than Fig.8 (a). However, the cladding of Fig.8 (a) was better than that of Fig.8 (b).

The thermal conductivity of the copper roll was larger than that of the mild steel roll. When the AA3003 strip was solidified by the copper roll, the temperature of AA3003 strip was lower than suitable temperature for connecting condition. On the other hand, when the mild steel roll was used, the temperature of strip became suitable temperature for connecting.

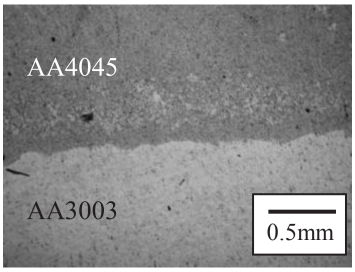


(a) Molten metal poured into the first and the second layers

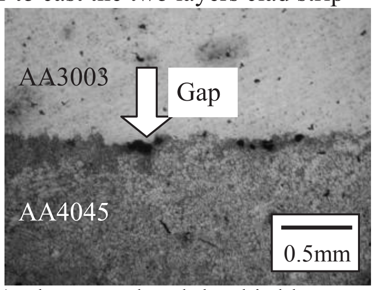


(b) Molten metal poured into the second and the third layers

Fig.8 Schematic illustration showing the roll caster to cast the two layers clad strip



(a) The first and the second layers



(b) The second and the third layers

Fig.9 Cross section of the two layers clad strip

6. Experimental condition of the three layers clad strip

Cast temperature of the first layer and the third layer was decided by preliminary experiment. The experimental conditions were shown in Table 1. The roll-roll gap was 2mm. The load of the rolling was 18N/mm (per unit width). In Fig.2 the weight of the first plate was 5N, and the second plate was 8N. The roll speed was 20m/min.

Table 1 Experimental conditions

First Strip	Cast temperature	700 [^{o}C]
	Solidification length	110 [mm]
Second Strip	Cast temperature	655 [^{o}C]
	Solidification length	100 [mm]
Third Strip	Cast temperature	750 [^{o}C]
	Solidification length	80 [mm]

7. Result of the three layers clad strip

The three layers clad strip could be cast by the process shown in Fig.2. The as cast clad strip could be cold rolled. The cross section of the three layers clad strip after cold rolling was shown in Fig.10. The three layers clad strips could be connected, and the interfaces of clad strip were clear. The connecting condition of the clad strip was investigated by bending test. The cross section of the clad strip after bending test was shown in Fig.11. The clad strip was bent continuously until broken. The clad strip was not peeled at the interface of the three strips.

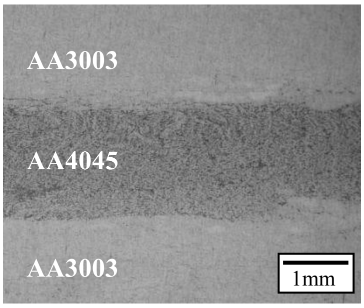


Fig.10 Cross section of the three layers clad strip after cold rolling

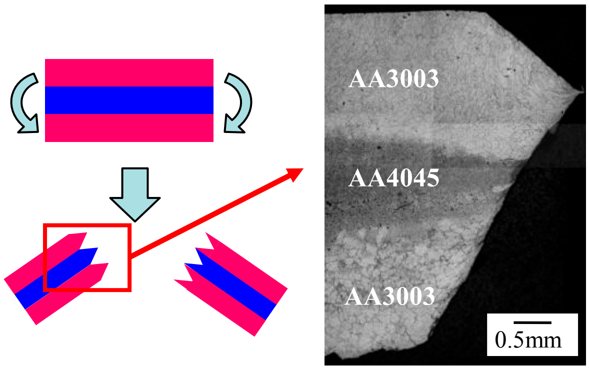


Fig.11 Cross section around the broken area by bending test

8. Conclusions

The different diameter twin roll caster to cast the three layers clad strip was devised and assembled. The characteristic of this twin roll caster was equipment of the movable plate. The movable plate was available to prevent the molten metals of clad strip from mixture. For the use of movable plate, this caster could cast the three layers clad strip, in which the liquidus temperature of the overlay strip is higher than that of the base strip. This caster could cast three layers clad strip at the roll speed of 20 m/min. The three layers clad strip was connected firmly, and they were not peeled by bending test. The process of this study could manufacture the clad strip at only one process.

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