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Clad strip casting by a twin roll caster

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ABSTRACT

Purpose: Of this paper is to realize the casting of the clad strip by only one process. Therefore, the investigation of the ability of the casting of the clad strip by a vertical type twin roll caster was operated. The aim of the use of the twin roll caster to make clad strip was in the reduction of the production-energy of the clad strip.

Design/methodology/approach: Used in the present study was a vertical type twin roll caster with the scriber. The scriber was used to prevent the mixture of the two kinds of the melts. The scriber was set at roll-bite, and the scriber contacted to the one of solidification layer. The melt was stopped by the scriber and the only the solidification layer was dragged by the roll.

Findings: The clad strip with the clear interface could be by the vertical type twin roll caster with the scriber. The scriber was useful to drag only the solid and semisolid layer. The two kinds of strips were connected strictly at the interface of the clad strip. The clad strip was not broken at the interface by the continuous bending.

Research limitations/implications: Are that 100 mm width-strip was cast in the present study. Ability of the clad strip that is wider than 100 mm was not clear. The control of the clad ratio was not investigated.

Practical implications: The twin roll caster devised and investigated in this report is useful to cast clad strip like the brazing sheet for the radiator of the automobile.

Originality/value: The vertical type twin roll cater to cast clad strip is original process. The scriber was used to prevent the mixture of the two kinds of melts. The scriber was not used in the previous research to cast clad strip at the twin roll caster, and use of the scriber was the first try.

Keywords: Casting; Twin roll caster; Clad strip; Interface of the clad strip

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MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

The fabrication of the clad strip needs many processes as shown below. The slab of the aluminum alloy is cast by the D.C. (Direct Chill) casting. The aluminium alloy strip is usually made from slab by scrapping, homogenization, hot rollings and cold rollings. The strips are connected after cleaning by hot rolling. Process saving is desired at the production of the clad strip for the energy saving. The twin roll caster can cast strip from molten metal directly. Therefore, the clad strip may be fabricated with low energy by the twin roll caster. If the clad strip is made directly from molten metal, the processes to make the thin strip and the process to connect the strips can be saved. This means that the process and energy can be saved drastically. However, there are few reports about the roll casting of the clad strip [1-3]. The twin roll caster to cast clad strip must be investigate to realize the fabrication of the clad strip from the molten metal directly.

The conventional twin roll caster for the aluminum alloy is not suitable for casting of the clad strip, because two kinds of melts can not be poured in to the roll bite without the mixture [4-14]. Therefore, the vertical type twin roll caster was adopted in the present study to prevent the mixture of the melts [15-17]. The vertical type is easy to pour the two kinds of molten metal using the launders from the crucible to the roll bite. The two kinds of molten metal must be prevented from the mixture. This was realized original method.The scriber was used to prevent the mixture of the molten metals. The scriber was only the plate, that was made from the mild steel and very simple. In the previous twin roll caster to cast the clad strip, the scriber has not been used [1-3]. The clad strip with clear interface could be cast by the process of the present study, which was the vertical type twin roll caster equipped with the scriber. The two strips were connected strictly, and two strips were not peeled off by bending. The fundamental characters of the vertical type twin roll caster equipped with the scriber to cast clad strip are shown in this report [20].

2. A twin roll caster for the clad strip

The advantage of the use of the twin roll caster for the fabrication of the clad strip is the process saving. The conventional process for make the clad strip and the process using the twin roll are shown in Fig.1. The process using the twin roll caster can save many processes, for example, scrapping on the surface, hot rolling, cold rolling, degrease, abrasive etc.

2.1. Roll casters to cast the clad strip

Figure 2 shows the schematic illustrations of a single roll caster and twin roll casters to cast clad strip [1-3]. The base process of (a) is melt drag process. Two nozzles are attached to the one roll. The upper side of strip cast by the single roll caster is free solidified surface. Therefore, surface is not flat, and the thickness distribution is not constant. The upper layer of the clad strip can not be cooled as same as the lower strip, as the upper strip does not directly contact to the roll. The melt of upper strip easily leak from the clearance between the nozzle and lower solidification layer. The melting point of the upper layer must be lower than that of the lower layer to prevent the melting of the lower layer. The base process of (b) is melt drag process, too. When the surface of the both strip is completely solidified, the strips are not connected. When the surfaces are semisolid condition, the strips can be connected. In this process, the control of the solidification of the surface is not easy. The solidification of the surface is controlled by the position of the meniscus of the melt in the nozzle and the roll speed. The hot rolling is not operated for connecting. The strips are connected by the fusion of the thin layer of the surface of the strip. The interesting feature of this process is that inlay type clad strip can be cast when the side-dam-plats are used. In the process (c), the lower strip is cast by the melt drag process and the upper strip is cast by the downward melt drag process.

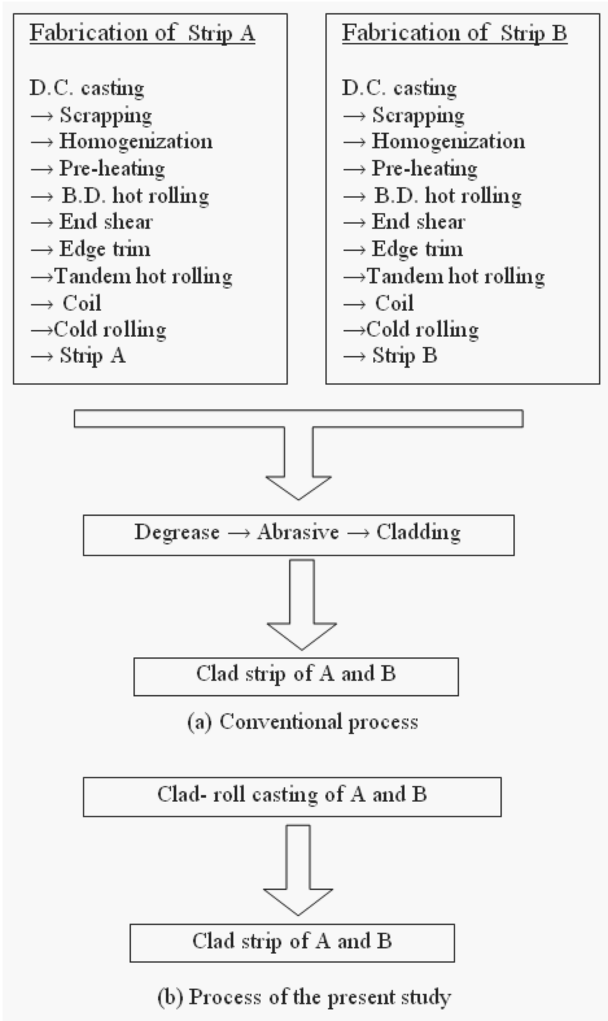


Fig. 1. Comparison of the process for making clad strip between the conventional process and the twin roll caster

The alloy which melting point is higher than the other must be lower strip so that the lower strip is not re-melted by the melt of the upper strip. The melt is dragged with the solidification layer from the nozzle through the clearance between the roll and the nozzle in the casting of the upper strip. The puddle of the melt of the upper strip is formed on the lower strip. This melt heats the surface of the lower strip up to the temperature enough to connect the upper and lower strips. Control of the cladding condition of (c) is easier than (a) and (b). The control of the cladding is operated by the distance from the meniscus of the melt of the lower strip to the roll gap. (d) is the process of the present study. The features of this process are vertical type and use of the scriber. The scriber contacts solidification layer of alloy A, and only the solidification layer of alloy A can be dragged by the rotation of the roll. The molten metal of the other alloy B contact with the solidification layer of alloy A. The liqidus line of the alloy B must be lower than that of A. The casting of clad strip using the (d) is easier than other processes by the effect of scriber.

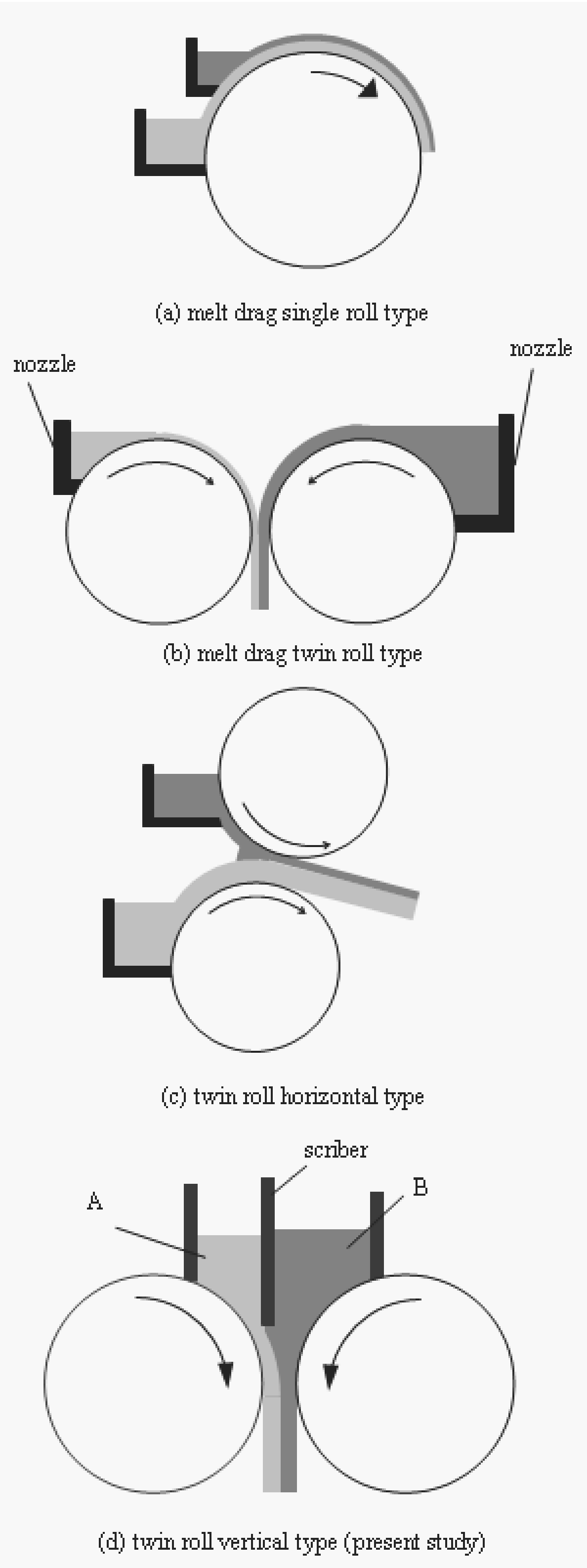
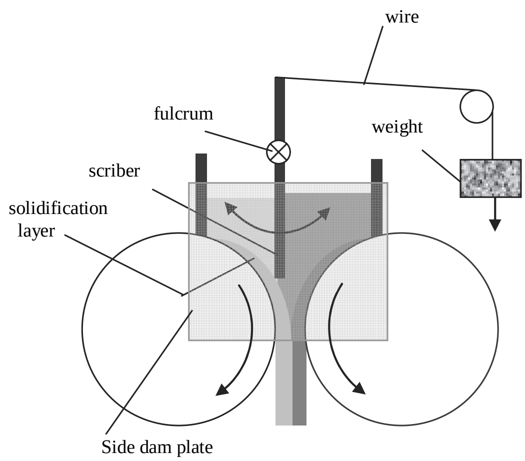


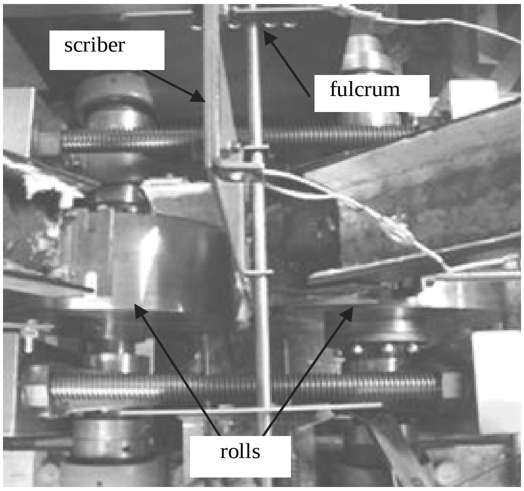
Fig. 2. Single roll caster and twin roll caster to cast the clad strips

2.2. A vertical type twin roll caster to cast clad strip of the present study

Figure 3 shows the schematic illustration and the photograph to explain the position of the scriber attached to the twin roll caster of the present study. The scriber is supported by the fulcrum, and it moves against the thickness of the solidification layer. The load, when the scriber contacts to the solidification layer, is controlled by the weight. When the weight is too heavy, the solidification layer can not tilt the scriber and be stopped by the scriber. When the weight is too light, the molten metal leaks. The optical weight was decided by try and error. The side dam plate is made from the mild steel of 3.2 mm thickness. The insulator cloth is attached to the side dam plate by the bond. The insulator cloth is useful to protect the leak of the melt between the roll and the side dam plate. The insulator cloth protects the reactance of the steel plate with the melt.



(a) schematic illustration of the side view



(b) photograph of the top view around the scriber

Fig. 3. Schematic illustration and photograph showing the scriber and its moving system which was attached to the twin roll caster to cast clad strip of the present study

Figure 4 shows the schematic illustration and photograph of the scriber. The scriber was made from the 3.2 mm thick-plate of the mild steel. The shape of the scriber could be made freely by the bending. The scriber is free from the broken by the thermal shock. The insulator paper was attached to the plate. The insulator paper prevented the plate from the reaction with the melt. The insulator paper is useful to prevent the leak of the melt between the side dam plate and the scriber or between the solidification layer and the scriber, too.

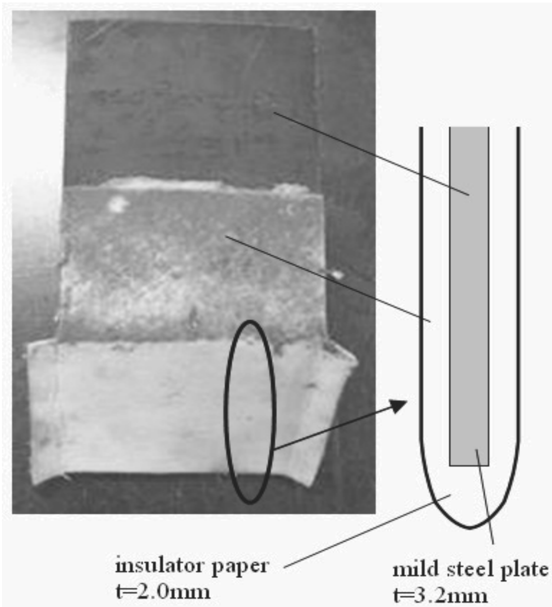


Fig. 4. Schematic illustration and the photograph showing the scriber

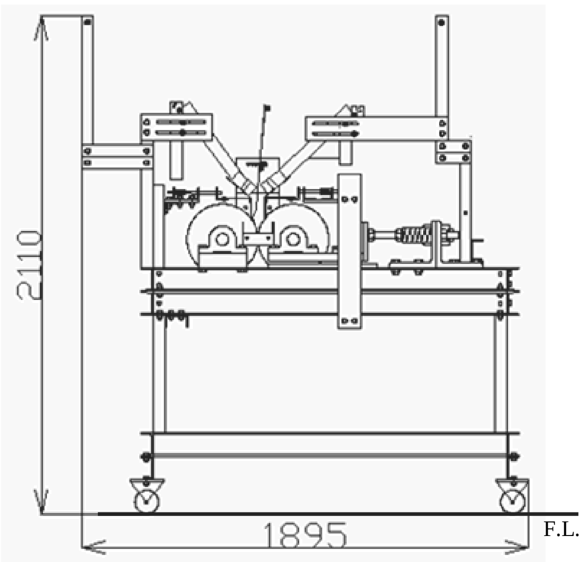


Fig. 5. Side view of the twin roll caster to cast clad strip of the present study

Figure 5 shows the side view of the twin roll caster for the clad strip. Roll-load was applied by the springs. The rolls were made by the copper. The diameter of the roll was 300 mm and the width was 100 mm.

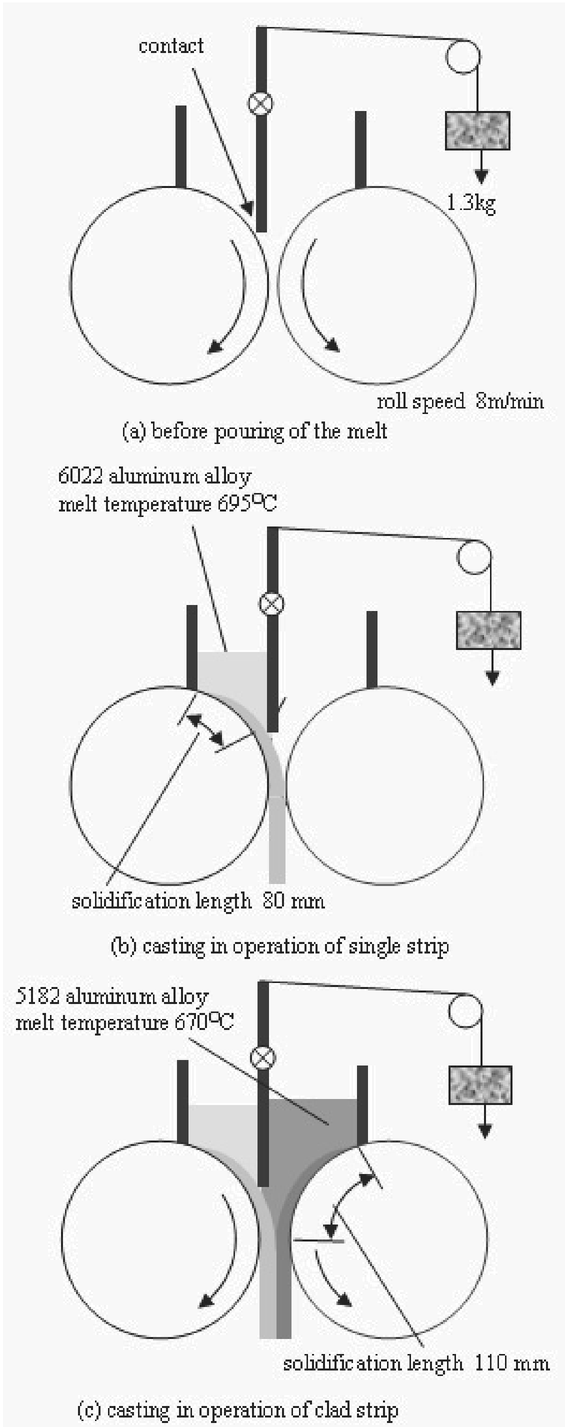


Fig. 6. Schematic illustration showing the operation of the casting of the clad strips

3. Experimental conditions

3.1. Casting of single layer strip

The effet of the scriber was investigated as the first step. The only solidification layer must be dragged by the effect of the contact of the scriber. The experimental conditions are as below. The 6022 aluminum alloy was used at this try. The melt temperature was 695^{O}C. The roll speed was 8m/min. The weight to push the scriber to the solidification layer was 1.3kg. When the weight was lighter than 1kg, the scriber did not move smoothly by the influence of the friction between the side dam plate and the scriber. Therefore, the melt leaked from the gap between the scriber and the solidification layer. When the weight was heaver than 1.5kg, the solidification layer could not pus up the scriber, and the solidification layer stuck. The rolls were rotated at the prescribed speed before pouring the melt. The scriber contacted to the rotating roll before pouring of the melt. The melt was poured into the nozzle after rotation of the rolls. The solidification layer pushed up the scriber and only the solidification layer went through under the scriber. The operation of the casting is shown at (a) and (b) in Fig. 6. The strip surface that contacted to the scriber was observed to check the leak of the melt. The cross section was observed to investigate the unevenness of the strip surface that contacted to the scriber.

3.2. Casting of clad strip

The operation of the clad strip is shown in (c) of Fig. 6, too. The melt of 5182 was poured after pouring of the melt of 6022. The alloy, that liquidus line is lower, was poured at second in order not to melt the solidification layer of the alloy poured at first. The load of the rolling was 0.14 kN. This load was too small to connect the two strips. The aim of the load was not bonding of the two strips but was to get the sound contact condition between two strips. The roll speed was 8m/min. This speed was higher than the conventional twin roll caster for the aluminum alloy [4-14]. The melt temperature of the 5182 was higher than the liquidus line of the 6022. This aim was that the scribed surface of the 6022 was heated up to the temperature suitable for bonding (Table 1).

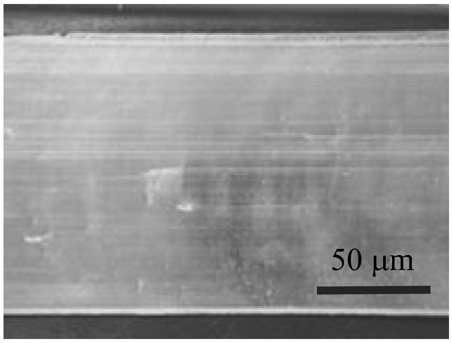
Table 1.
Experimental conditions

roll	diameter: 300mm, width : 300mm material: copper
nozzle	surface: insulator paper inside: mild steel plate , t: 3.2mm
side dam plate	surface: insulator cloth inside: mild steel plate, t:3.2mm
scriber	surface: insulator paper inside: mild steel plate, t:3.2mm weight: 1.3kg
material	5182: melt temperature 670^{O}C 6022: melt temperature 695^{O}C
contact length	5182: 110mm 6022: 80mm
roll speed	8m/min
roll load	0.14kN

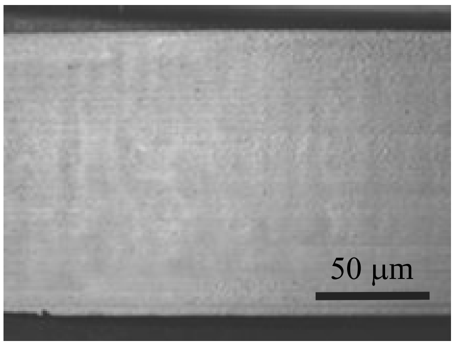
4. Result and discussion

4.1. Casting of single layer strip

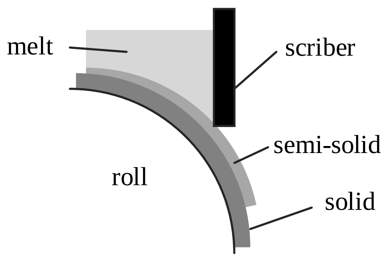
The single layer strip could be cast by the process shown in Fig. 6 (b). The strip was dragged by the roll without stuck by the scriber. The scriber followed the surface of the strip. Therefore, the melt did not leak from the gap between the scriber and the strip. The surface of the strip cast by Fig. 6(b) is shown at Fig. 7. The roll-contact surface of the strip was flat and it had metallic gloss. The roll-contact surface was same as surface of the strip cast by the vertical type twin roll caster without scriber. The scribed surface did not have metallic lustre. The small groove, that was trace of slide with the scriber, was observed. The effect of the scribe did not exist on the roll-contact surface of the strip.



(a) roll-contact surface

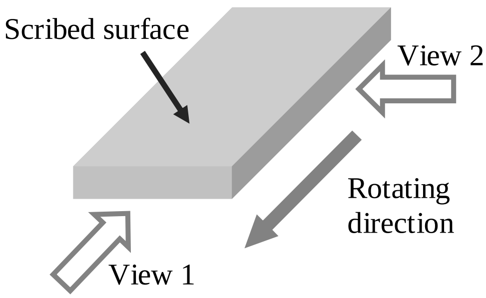


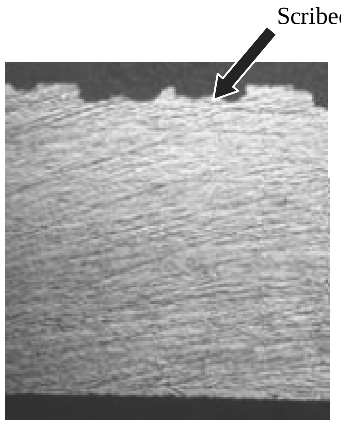
(b) scribed surface



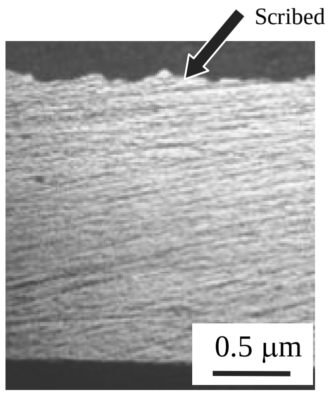
(c) schematic illustration showing the act of the scriber

Fig. 7. Surface of the single strip cast by the process of Fig. 6(b)





(a) View 1



(b) View 2

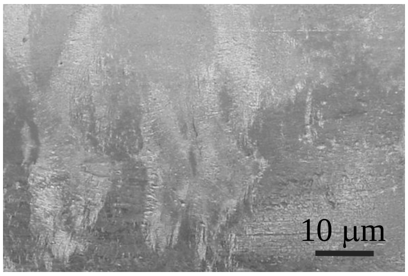
Fig. 8. Cross section of the single strip

The cross section of the single strip is shown in Fig. 8. In Fig. 8, upper is scribed surface and lower is roll-contact surface. The trace of the scribe is observed at the scribed surface. The height of the groove was lower than 0.1 mm. The shape of the groove was irregular. The area where the metal was soft might become channel by the scribe. There was no crack at scribed surface. The scribe did not influence on the strip except for groove at the scribed surface.

4.2. Casting of clad strip

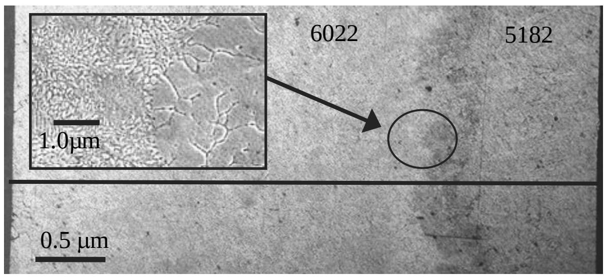
The clad strip could be cast by the process shown in Fig. 6. The surface of as-cast clad strip is shown in Fig. 9. The primary strip of 6022 was not melted by the heat from the melt of the secondly strip of 5182. There was no difference between the surfaces of the single strip and the clad strip.

(a) 6022 (first strip)

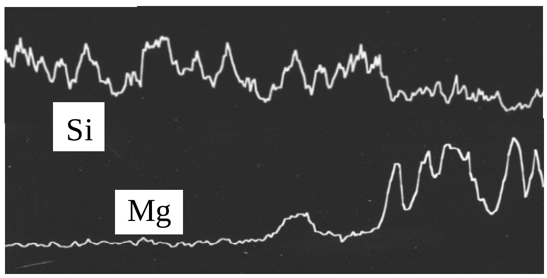


(b) 5182 (second strip)

Fig. 9. Surface of the as-cast clad strip



(a) cross section of as-cast clad strip

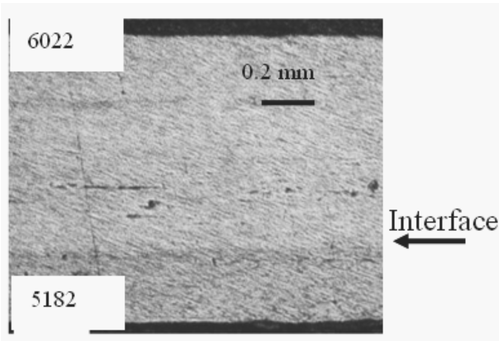


(b) line analysis

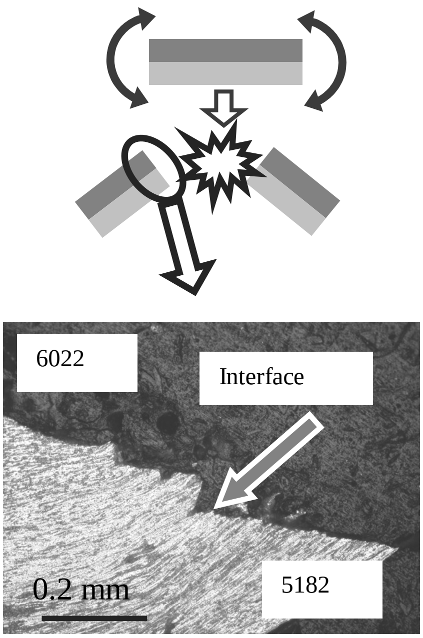
Fig. 10. Cross section of the as-cast strip and result of the line analysis

The cross section of as-cast clad strip and result of the line analysis is shown in Fig. 10. There was not porosity at the interface between the 6022 strip and 5182 strip. The wetting condition between the scribed surface of 6022 and the melt of the

5182 was sound. It is thought that the re-melted zone of the 6022 was very narrow from the micrograph of the cross section and the line analysis. The contact time between the strip of 6022 and the melt of 5182 was shorter than 0.6s. Therefore, re-melting time of 6022 strip was very short. The melt of 5182 contacted to the scribed surface of 6022 solidified rapidly before it melted 6022. However, the surface of scribed surface of the 6022 strip was heated up to the enough temperature to clad the two strips.



(a) cross section of as-rolled strip



(b) cross section around the broken area by bending

Fig. 11. Result of the cold rolling and the bending test of the as-rolled strip

The cold rolling and bending test were operated to check the joining condition at the interface of the two strips. The cross section as-rolled strip is shown in Fig. 11(a). When the joining is not enough, the alligator crack occurs at the cladding interface. The alligator crack did not occur at the cladding interface of clad strip cast by the process of the present study. The clad ratio of the as-rolled strip was as same as the clad ratio of the as-cast strip. Warp and curve did not occur after cold rolling. The surface of the clad strip became sound by the cold rolling.

Result of the bending test of as-rolled strip is shown in Fig. 11(b). The clad strip was bent continuously until broken. The clad strip was not peeled at the interface of the two strips. It is thought that the two strips were joined firmly at the interface.

The clad strip cold rolled down to 1mm was heated at 450^{O}C for 4 hours in the electric furnace. The blister was not observed at both surfaces. The blister is produced at the position where the two strips did not join. This result means that there were few positions where the two strips did not connect in the clad strip cast by the process of the present study.

5. Conclusions

The vertical type twin roll caster to cast the clad strip was devised and assembled. The casting of the clad strip was tried using the twin roll caster of the present study. The characteristic of this twin roll caster was equipment of the scriber. The role of the scriber was to prevent of the mix of the two kinds of melts those were solidified into the strips. This caster could cast clad strip of 6022 and 5182 aluminum alloys at the speed of 8m/min. The two kinds of melts were not mixed, and the interface between the two strips was clear by the act of the scriber. The casting speed of this caster was higher than that of the conventional twin roll caster for aluminum alloy. The as-cast strip could be cold-rolled down to 1mm without occurrence of the alligator crack. Two strips were joined firmly, and they were not peeled by the bending test. The clad strip, in which the two strips could be connected firmly, could be cast directly from two kinds of molten metals by the vertical type twin roll caster of the present study. The process of the present study could produce the clad strip at only one process. This process is very useful to save the energy to make the clad strip.

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