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Roll casting of 5182 aluminium alloy

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ABSTRACT

Purpose: of this paper is investigation of the ability of the high speed roll casting of 5182 aluminium alloy. Appropriate twin roll caster to cast the 5182 strip was researched.
Design/methodology/approach: Method used in the present study was an unequal diameter twin roll caster and a vertical type high speed twin roll caster equipped with mild steel rolls without parting material.
Findings: are that the vertical type high speed twin roll caster was effective to cast 5182 strip at high speed. 5182 could be cast at 10 times higher speed than a conventional twin roll caster for aluminium alloy. 5182 could be cast by the mild steel roll using no-parting material without sticking.
Research limitations/implications: is that ability of casting of the wide strip, that is wider than 600 mm, could not be investigated.
Practical implications: 600 mm-width 5182 strip could be cast and this width is enough for some structural parts. 5182 could be cast into the strip at high productivity and low energy using the economy equipment and no-consumable good.
Originality/value: The method to make economy sheet metal of aluminium alloy is imported. The economy alloy and economy process are essential to get economy aluminium alloy sheet.
Keywords: Casting; Twin roll cater; 5182 aluminium alloy; Strip

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1. Introduction

Recently, economy aluminium alloy sheets for automobile are desired from the environmental point. 6016 and 6022 aluminium alloy is popular aluminium alloy for the body sheet of the automobile. In this alloy, the Fe content is limited lower than 0.2 mass% to get excellent formability. Especially, the bending ability is influenced by the Fe content. The 6016 and 6022 aluminium alloys are expensive for the limitation of Fe content. The method to make economy sheet metal of aluminium alloy is desired. The economy alloy and economy process are essential to get economy aluminium alloy sheet. The roll casting is one of economy process which can make aluminium alloy sheet metal at low cost. The twin roll caster makes Al-Si-Fe intermetallic smaller by the rapid solidification. The Al-Si-Fe intermetallic is the cause of decrease of formability. When the size of the Al-Si-Fe intermetallic is small, the decrease of the formability becomes low. Therefore, the twin roll caster can makes limitation of the Fe content high without deterioration of the formability. However, the productivity of the conventional twin roll caster for aluminium alloy is low. The cost of the sheet cast by the roll casting becomes lower, if the roll speed can be increased. We have investigated the high speed roll vesting to brake through the problem of the low casting speed of the twin roll caster for the aluminium alloy. The roll casting at the speed of 60 m/min was attained.

5182 can be used for body sheet and structural part of the automobile. The plate of 5000 series of aluminium alloys is used for the structural parts. 5182 aluminium alloy is popular, and 5182 is used at many products. Out put of 5182 is larger than that of 6016 and 6022. This is the advantage at the point of the recycle. 5182 is economy than 6022 and 6016 by the effect of large out put. 5182 has advantage at the point of the cost, too. They say that the twin roll casting of 5182 is difficult as the freezing zone of the 5182 is wide. If the strip of the 5182 can be cast by the twin roll caster, the economy body sheet is gained from the points of alloy cost and productive process. Moreover, the cost of the strip becomes lower by the adaptation of the high speed roll casting.

In the present study, ability of the high speed twin roll casting of 5182 aluminium alloy was investigated. The high speed twin roll casting was tried by two kinds of twin roll casters. One is an unequal diameter twin roll caster and the other is a vertical type high speed twin roll caster. In the previous study of the high speed twin roll casting, the copper roll was used to increase casting speed. The mild steel roll was used to make the roll-cost lower in stead of the copper roll in the present study. Some devices were adopted to increase the roll speed. In this report, surface condition, microstructure and bending ability of the 5182 strip cast by the high speed twin roll caster were shown.

2. Twin roll casters

In the present study, two kids of twin roll castes were used to investigate the castability of the 5182 strip at high speed. One was an unequal diameter twin roll caster (UDTRC) and the other was a vertical type high speed twin roll vaster (VHSTRC) [1-6]. These twin roll caters are shown in Figure 1. These two kinds of twin roll caster were different from the conventional twin roll caster for aluminium alloy (CTRCA) [7-18].

One of the characteristic of the UDTRC is that the lower roll is larger than the upper roll. The position of the upper roll of the present study was different from other UDTRC [19-20]. The position of the upper roll of the present study has advantages as below. One is easiness of the start of the casting, and the other is ability of the low temperature casting. The low temperature casting is useful for high speed roll casting. The melt was poured on the lower roll from the launder. Melt did not leak from the gap between the rolls. The reason was that the roll speed was higher than flow of the melt and the some mount of melt solidified on the lower roll before the melt reached to the roll bite. In this way, the countermeasure was not needed at the start of the casting. When the low temperature casting was operated using the CTRCA, the plug occurred at the tip by the solidified metal. In the UEDTRC, the plug in the tip was free because the tip was not used and the melt was poured directly on the lower roll. The UDTRC is suitable for low temperature casting in this reason. Solidification length was decided by the upper and the lower plate, and those plates were contacted to the upper roll and the lower roll respectively. The solidification layer by the lower roll was thicker than that by the upper roll. This reason is that solidification layer of the lower roll was longer than that of upper roll. The solidification length of the lower roll of the UDTRC is longer than the solidification length (set back). This is one of the reasons of the ability of the high speed roll casting of the UDTRC.

The VHSTRC is different from the vertical type twin roll caster for the steel at the point of the use of the nozzle plate. The nozzle plate is used at the VHSTRC. The solidification length was decided by the position of the nozzle plate. The nozzle plate can prevent the fluctuation of the strip-thickness that occurs by the bouncing of the melt head. The hydrostatic pressure at the tip of the nozzle becomes higher, and the vibration of the meniscus becomes small. The ripple pattern on the strip surface can be prevented by the hydrostatic pressure, and the contact condition between the melt and the roll becomes uniform. As the result, the surface condition becomes sound by the effect of the nozzle plate.

In the previous study about the high speed twin roll caster, the separating force (roll load) was restricted lower as the copper roll was used to improve the cooling ability [1-5]. When Mg is added to the aluminium, porosity occurs at interface between the solidification layers. Therefore, the separating force must be increased larger than previous high speed twin roll caster to get rid of porosities. Separating force per unit increased from 0.1 kN/mm to 0.7 KN/mm. This separating force was very small rather than that of the CTRCA.

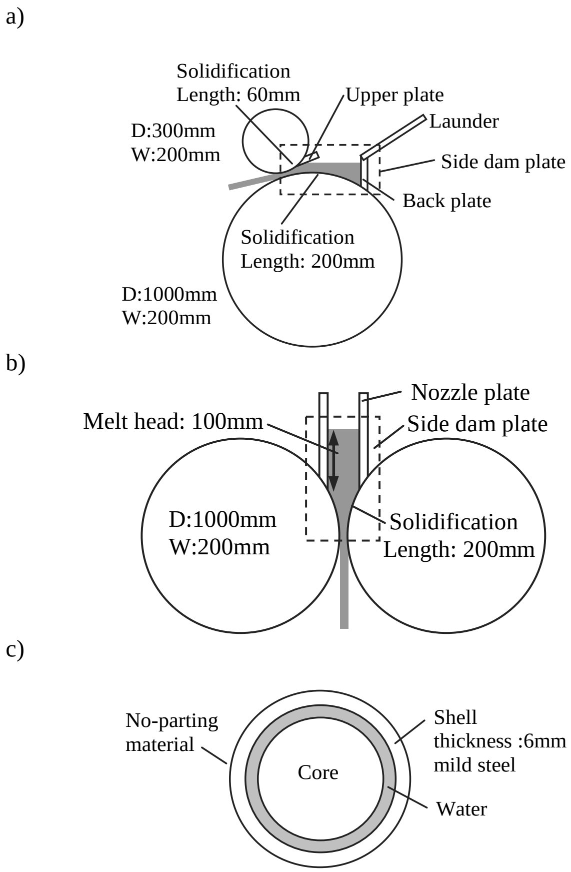
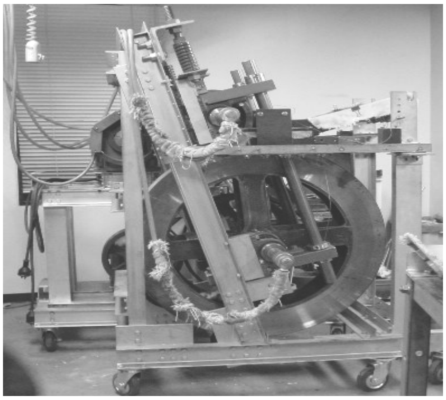


Fig. 1. Schematic illustrations of the casters and roll: a) unequal diameter twin roll caster, b) vertical type high speed twin roll caster, c) cross section of the roll

a)



b)

Fig. 2. Photographs of twin roll casters of the present study: a) unequal diameter twin roll caster, b) vertical type high speed twin roll caster in operation of casting. Strip is 5182 and casting speed is 60 m/min

The schematic illustration of the roll is shown in Figure 1, too. The roll was made from mild steel. In the CTRCA, tool steel for hot working is usually used for the roll. The thickness of the shell is usually from 25 mm to 60 mm in the CTRCA. In the present study, the separating force was not so large, therefore mild steel was used. The thickness of the shell is 6 mm to cool the shell rapidly. The thermal conductivity of the mild steel is larger than that of the tool steel for hot working. The large thermal conductivity and thin shell were suitable for the increase of casting speed. The side view of the UEDTRC and the VHSTRC in operation of the casting are shown in Figure 2.

3. Experimental conditions

The experimental conditions are shown at Table 1 and Table 2. The casting speed (roll speed) of the UEDTRC was 30 m/min and that of the VHSTRC was 60 m/min. The casting speed of the VHSTRC could be set higher by the effect of the hydrostatic pressure increased by the nozzle plate. The molten metal was poured from the crucible through the launder. When the melt was poured, the rolls were rotated at casting speed. Initial operation for the start of the casting was not needed. Super heat of the melt was 20^{O}C, and this temperature was measured at the crucible. Metal was melted in the crucible under the air using the electric furnace. Insulator paper was attached to the mild steel plate, and this was used for a nozzle plate of the VHSTRC, an upper plate and a lower plate of the UDTRC. These plates were not pre-heated. Initial roll gap was set at 1 mm.

Table 1.
Experimental condition of an unequal diameter twin roll caster

Upper roll	Material: mild steel Diameter: 300 mm, width: 200 mm Parting material: no-use Solidification length: 60 mm
Lower roll	Material: mild steel Diameter: 1000 mm, width: 200 mm Parting material: no-use Solidification length: 200 mm
Roll speed	30m/min
Material	5182 Superheat: 20 ^{O}C 7 kg

Table 2.
Experimental condition of an unequal diameter twin roll caster

Roll	Material: mild steel Diameter: 1000 mm, width: 200 mm Parting material: no-use Solidification length: 100 mm
Roll speed	60m/min (90m/min investigation of ripple pattern)
Material	5182 Superheat: 20 ^{O}C 7 kg

The parting material is used to prevent the sticking of the strip to the roll in the CTRCA. The parting material is useful to make surface of the strip sound, too. The parting material becomes the heat resistance between the roll and the melt (or strip). If the parting material may not be used, the roll speed can be increased. The occurrence of the sticking and the force of the sticking depend on the alloy. When the Mg was contained at some mount, the sticking did not occur. Therefore, the parting material was not used at the roll casting of 5182 strip in the present study. The roll-cast strip becomes economy by no-use of the parting material.

4. Results and discussion

4.1. Unequal diameter twin roll caster

The strip of the 5182 could be cast continuously. The strip did not stick to the upper and lower roll without parting material. The surface of the roll before and after casting is shown in Figure 3. Aluminium coating occurred after 2 rotations. The aluminium coating might acted like the parting material. The aluminium coating was not uniform. The pattern of the roll coating was as same as the pattern of the surface of as-cast strip. The surface of the strip cast by the mild steel roll was not as good as the surface of the strip cast by the copper roll. The method to make aluminium coating uniform is essential to make surface sound. The aluminium coating of the upper roll was different from that of the lower roll. This reason was derived from the difference of the vibration of the meniscus at the tip of the plate. The hydrostatic pressure of the melt at the tip of the upper plate was lower than that of the lower plate. Therefore, the vibration of the melt at the tip of the upper plate was vigorous and the upper surface of the strip became worse. The ripple pattern became light at lower speed or high hydrostatic pressure.

a) b)

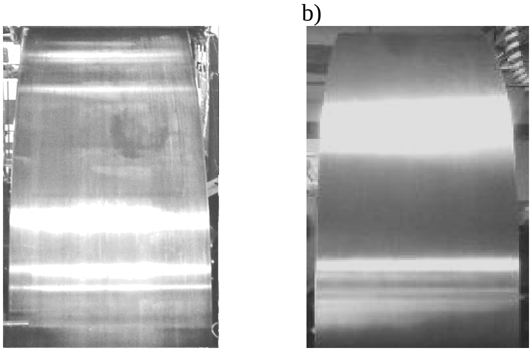


Fig. 3. Lower roll surface of an unequal diameter twin roll caster a) before casting, b) after casting. Aluminum coating occ

The surface of as-cast strip is shown in Figure 4. The upper surface was different from the lower surface. The ripple pattern was existed on the upper surface. The ripple pattern was made from dull part and luster part. The thickness of the luster part was 3.0 mm and that of the dull part was 2.9 mm. The thickness of the dull part was thinner than that of luster part. The cause of the difference of the thickness came from the difference of the contact condition between the melt and the roll. The cause of the dull was thought to be thicker oxide film than luster part. Therefore, heat transfer was worse at the dull part. The crack was observed at dull part of the upper surface as shown in Figure 4a. The dull part was not cooled enough like the luster part when strip was rolled at roll bite, and the dull part had not enough strength like luster part. As the result, the crack occurred at the dull part. The crack was not observed at the lower surface. The solidification length of the lower roll was longer than that of the upper roll, and lower side of the strip was enough cooled. Therefore, the crack did not occur at the lower side.

The as-cast strip could be cold rolled down to 1mm without the annealing. The surface of the cold-rolled strip became better than that of the as-cast strip. Thickness distribution was improved, too. The some cracks existed at as-cast strip were erased, and some cracks occurred at the cold rolling. The crack occurred at thin part by cold rolling. The crack at thin part occurred by tension stress. The deformation of rolling direction at the thin part was smaller than other part. Therefore, the thin area was tensioned. The cracks, which occur at the cold rolling, can be prevented by the roll casting using the grooved roll [6]. The lower surface of the strip was better than the upper surface after cold rolling (Fig. 5).

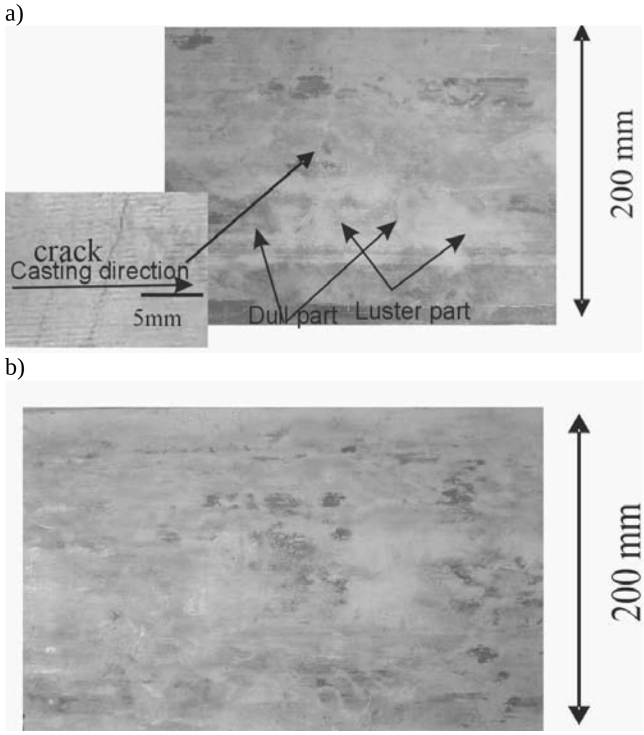


Fig. 4. Surface of as-cast strip cast by an unequal diameter twin roll caster: a) upper surface, b) lower surface

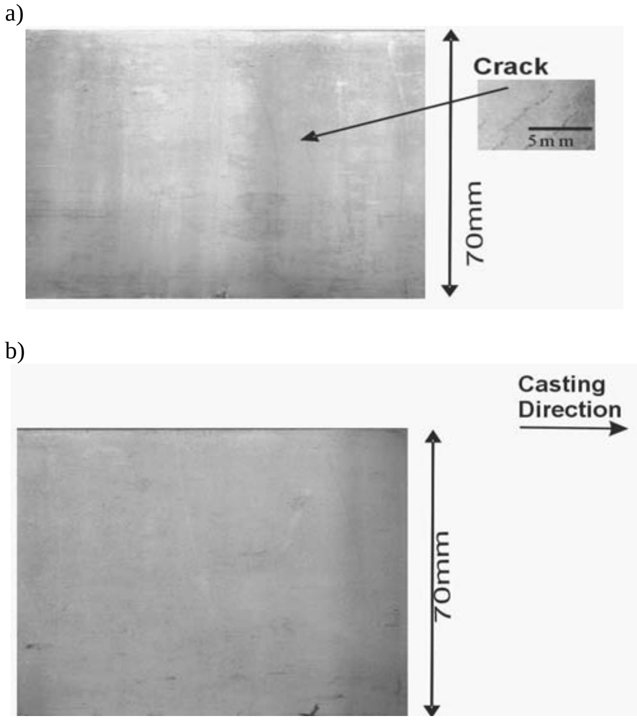


Fig. 5. Surface of the cold-rolled strip down to 1mm without the heat treatment: a) upper surface, b) lower surface

The microstructure of the 5182 strip cast by the unequal diameter twin roll caster is shown in Figure 6. The microstructure of as-cast strip was not uniform and symmetrical at the thickness direction as shown Figure 6a. The reason of unsymmetrical microstructure was that the solidification length of the upper and lower roll was not same. The solidification length of the upper roll was shorter than that of the lower roll, and the thickness of solidified layer by the upper roll was thin. The microstructure at interface between the upper and lower solidification layer was globular as shown in (2) of Figure 6a. This is the typical microstructure by the low temperature casting. In this area, Mg segregated at the grain boundary. The microstructure became coarse at the upper side of the solidification layer cast by the lower roll as shown in (3) of Figure 6a. This reason is that the heat transfer between the lower roll and solidification layer became small when upper side solidified, and the cooling rate of upper side became low. The strip shrinks at width direction as the temperature of the solidification layer becomes low, as the result, the contact condition between the roll and the solidification layer becomes worse. If the solidification length is shorter or the roll speed is higher, this coarse microstructure becomes fine. The microstructure near the lower side was fine as same as that near the upper side.

The annealing of 450^{O}C-10.8ks was operated on the as-cast strip. The microstructure after annealing is shown in Figure 6b. The microstructure did not become uniform after annealing. The segregation of Mg was improved by the annealing.

The microstructure of the cross section of the strip after cold rolling of as-cast strip is shown in Figure 6c. The microstructure of as-cast strip was not symmetric. However, the cold rolling could be operated without occurrence of the crack at the boundary between the upper and lower solidification layer.

180 degrees full bending was operated to investigate the formability of roll cast 5182 strip. 180 degrees full bending was assumed the hem forming. The as-cast strip was cold rolled down to 1 mm without annealing. The cold rolled strip was annealed at the condition of 450^{O}C-10.8ks. 5% of strain was induced to the annealed strip assuming the press-forming. The strain-induced strip was bent at the condition showing Figure 7 and Table 3. The result of the 180 degrees full bending is shown in Figure 8. The cold rolling direction was as same as the casting direction. Figure 8 shows outer surface after bending. The result was influenced by the bending direction. When the bending direction was cross to the casting (rolling) direction, the degree of crack was low. The result of the lower surface was better than that of the upper surface. This reason is not clear. The crack occurred at casting and the cold rolling might affect the result of the bending. When the cold rolling was operated to the width direction, the result became better. The rolling direction influenced the crack on the outer surface after bending.

Table 3.
Conditions of 180 degrees full bending. Type A, B, C and D is coincide with the type of Figure 8

Type	Direction	Outer surface
A	Casting	Upper side
B	Casting	Lower side
C	Width	Upper side
D	Width	Lower side

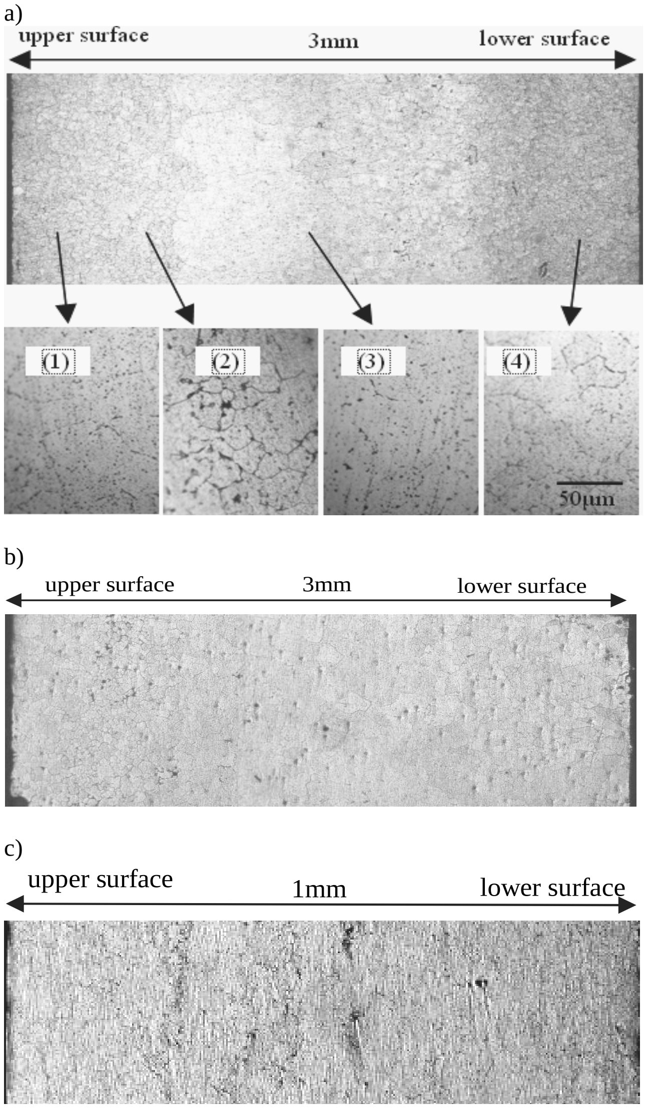


Fig. 6. Cross section of 5182 strip cast by an unequal diameter twin roll caster: a) microstructure of the cross section of as-cast strip, b) microstructure of the cross section of as-cast strip after annealing. Annealing condition: 450^{O}C-10.8ks, c) microstructure of the cross section of as-cast strip

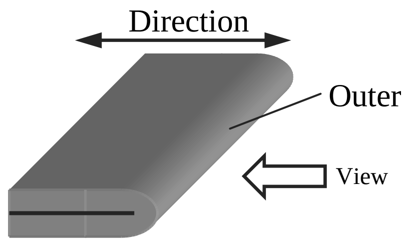


Fig. 7. Schematic illustration showing the conditions of the 180 degrees full bending of Table 3

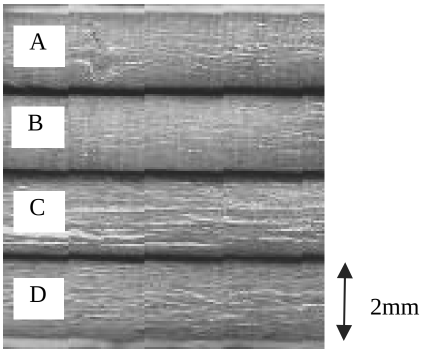


Fig. 8. Results of the 180 degrees full bending test. A, B, C and D coincides with them shown in Table 3

4.2. Vertical type high speed twin roll caster

5182 strip could be cast at speed of 60 m/min by the VHSTRC. The casting speed of 60 m/min much higher than that of the CTRCA. The casting speed of the CTRCA is usually slower than 10m/min. The strip did not stick to the roll without the parting material. The as-cast strip and the roll after casting are shown in Figure 9. The both edges were strait and the width was constant. The ripple pattern existed at the strip and the roll. The ripple pattern of the VHSTRC was extremer than that of UEDTRC. The vibration of the meniscus at the tip of the nozzle plate became vigorous as the roll speed increased. The roll temperature after every rotation became higher as the roll speed increased. The ripple pattern became vigorous by the influence both of the vibration of the meniscus and roll temperature. The ripple pattern on the strip existed at the regular interval. The ripple pattern of the aluminium coating on the roll surface overlapped on the previous ripple pattern of the aluminium coating with deviation at every rotation. The ripple pattern on the strip was copied on the roll surface. However, the pattern on the roll was not copied on the strip surface. The aluminium coating on the roll surface did not hardly influence on the occurrence of the ripple pattern on the strip surface. The crack was not existed on the strip surface. The surface of the strip cast by the VHSTRC was better than that cast by the UEDTRC.

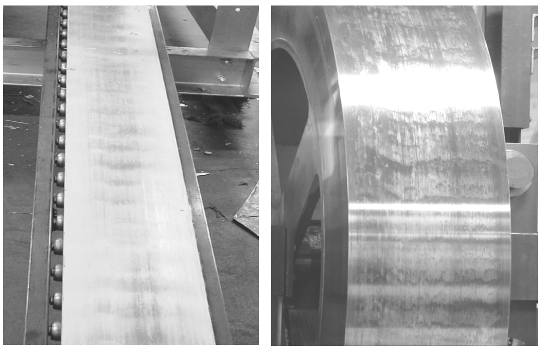


Fig. 9. 5182 as-cast strip and roll coating of a vertical type high speed twin roll caster

The as-cast 5182 strip could be cold rolled down to 1 mm without annealing. The surface of the cold rolled strip was shown in Figure 10. The crack did not occur at strip surface. The condition of the cold rolled 5182 strip, which cast by the VHSTRC, was better than that cast by the UEDTRC. The ripple pattern on the strip cast by the VHSTRC was clear than that cast by the URDTRC by visual investigation. However, the strip cast by the VHSTRC was not broken at the thin spot by the cold rolling. This reason is that the thickness distribution of the strip cast by the VHSTRC was better than that by the UDTRC.

Fig. 10. Surface of the 5182 strip after cold rolling down to 1mm without heat treatment

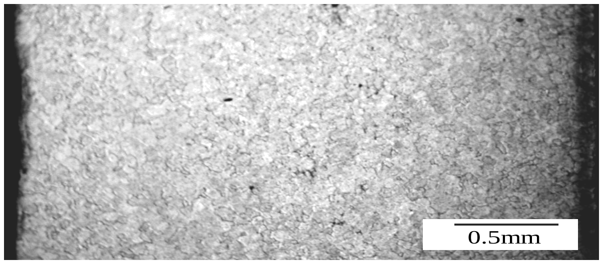


Fig. 11. Microstructure of as-cast 5182 strip cast by a vertical type high speed twin roll caster at speed of 60 m/min

The microstructure of as-cast 5182 strip is shown in Figure 11. The nonuniformity of microstructure at thickness direction of the strip cast by the VHSTRC was less than that cast by the UEDTRC.The coarse structure did not exist at the centre area. This is the effect of casting speed and thin-thickness. The casting speed of the VHSTRC was twice higher than that of the UEDTRC.

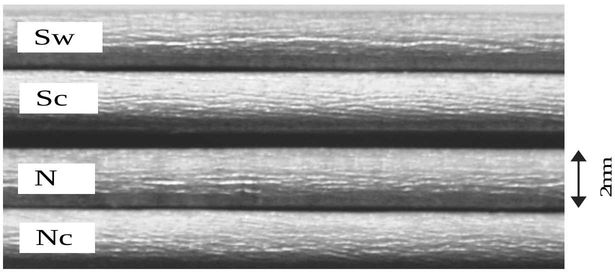


Fig. 12. Result of 180 degrees full bending of A5182 strip cast by a vertical type high speed twin roll caster. "S" shows 5% strain was induced after annealing of 450^{O}C-10.8ks. "N" shows strain was not induced. "w" shows the direction of Figure.7 is width direction. "c" shows the direction of Fig.7 is casting (rolling) direction

Fig. 13. Roll casting of 600 mm-width 5182 strip at speed of 60 m/min. Roll diameter was 600 mm, and width was 600mm. Structure of the roll is as same as Figure 1c

The result of the 180 degrees full bending test was shown in Figure 12. The as-cast strip was cold rolled down to 1mm, and that was annealed at condition of 450^{O}C-10.8 ks. In Figure 12, “Sw” and “Sc” shows the result of 5%-strain induced strip before the bending. “Nw” and “Nc” shows the result of the bending of the annealed strip. The outer surface became coarse. However, the crack did not occur. The coarseness increased when the strain was induced. When the bending direction was cross to the casting direction, the coarseness became light. The result of the 180 degrees full bending of the strip cast by the VHSTRC was better than that of the strip cast by the UEDTRC.

It became clear that the VHSTRC is suitable for the strip casting of 5182 than UEDTRC. Ability of roll casting of wide strip using the VHSTRC was investigated, too. The roll casting of 600mm-width strip is shown in Figure13. The 600mm-width 5182 strip could be cast at speed of 60 m/min. There was no difference between the 200 mm-width and 600 mm-width. It is thought that more wide 5182 strip can be cast using the VHSTRC.

5. Conclusions

Roll casting of 5182 aluminium alloy strip was tried by the unequal diameter twin roll caster (UEDTRC) and the vertical type high speed twin roll caster (VHSTRC). The 5182 strip could be cast by both twin roll casters at speeds higher than the conventional twin roll caster for aluminium alloy. It became clear that 5182 could be cast without sticking to the roll using no-parting material. As-cast strip could be cold rolled down to 1 mm without annealing. The VHSTRC was superior to the UEDTRC at the below points. They are uniformity of the microstructure at thickness direction, bending test and the casting speed. 600 mm-width 5182 strip could be cast using the VHSTRC, too. This shows the ability of the VHSTRC that commercial size 5182 strip may be cast by the VHSTRC.

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