

High speed twin roll casting of 6016 aluminium alloy strip

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ABSTRACT

Purpose: of this paper is to clear the possibility of high speed roll casting of aluminum alloy strip. In the body of the automobiles, a sheet of 6016 aluminum alloy is adopted for the outer panel. Therefore, casting of 6016 was tried in this study. Characteristics of roll cast 6016 were investigated.

Design/methodology/approach: was a high speed twin roll caster. The high speed twin roll caster was designed to overcome the low castability of the twin roll caster.

Findings: are as below. 6016 alloy could be cast into the strip continuously at the speed of 60m/min. The thickness of the strip was 3.4 mm. The microstructure at as-cast and after T4 heat treatment was shown. The microstructure was very fine. The mechanical properties were investigated by the tensile test and 180 degrees vending test. The as-cast strip could be cold rolled without homogenization to 1mm. Result of tensile test was tensile strength was 230MPa, 0.2% proof stress was 118MPa and elongation was 33%. 6016 strip of T4 heat treatment could be bent 180 degrees without occurrence of crack at the outer surface or breaking.

Research limitations/implications: is the width of the strip was 100 mm. It is necessary to test twin roll caster equipped wide rolls.

Practical implications: are as below. The mechanical properties of the roll-cast 6016 were enough for the sheet metal for the automobile. The low productivity of the twin roll caster could be improved.

Originality/value: is that 6016 strip could be cast continuously at speed 60 m/min and this strip had good mechanical properties.

Keywords: Casting; Metallic alloys; Twin roll casting; Thin strip; Rapid solidification; Cooling slope

1. Introduction

In automobiles, decreasing weight is one of the most important problems should be solved. Using parts of aluminum alloy instead of parts of steel enables the weight of the automobiles to be decreased. In the body of the automobiles, sheets of 6000 series aluminum alloys are adopted for the inner and outer panel [1-3]. However, sheet products of aluminum alloy

are more expensive than sheet products of steel. It is desirable to economically produce aluminum alloy strip, and twin roll caster has this capability. Aluminum alloy strip can be cast directly from molten metal by a twin roll caster. The twin roll caster for aluminum alloy has several advantages, including low equipment cost, low running cost, energy saving and space saving. It is possible that improvement of the ductility of the aluminum alloy for casting by the rapid solidification using the twin roll caster [4] [5]. However, the strip casting using conventional twin roll caster

has disadvantage, too. It is low casting speed. The low casting speed becomes cause of low productivity. In the present study, the improvement of the low casting speed was tried by increasing the cooling rate at the roll caster. A high-speed twin roll caster [6-11] of vertical type was designed and assembled to cast aluminum alloy strip. Strip casting of 6016 alloy was tried using a vertical type twin roll caster. Properties of the cast strip were investigated by the metallography, a tension test and a bending test.

2. Experimental conditions

Figure 1 shows a schematic illustration of the high-speed twin roll caster. One of most important features of the twin-roll caster is rapid solidification. In the present study, some improvements were implemented in order to increase cooling rate. The conventional twin roll caster for aluminum alloys uses steel rolls. Copper is higher in thermal conductivity than steel, making copper rolls suitable for the twin roll caster. The high-speed twin roll caster adopts copper rolls. When the copper rolls are used, hot rolling under large load is difficult. Load affects the heat transfer coefficient between the roll and the strip. The low load of enough heat transmission was added: the load of the high-speed twin roll caster is 1/10 to 1/100 the load of the conventional twin roll caster. The hot rolling is hardly performed.

Lubricant is sprayed on the roll surface in order to prevent sticking of the strip to the roll in the conventional twin roll caster. The lubricant adds heat resistance, lowering the heat transfer coefficient between the roll and the strip. Therefore, without lubricant, the cooling rate of the strip increases. In high-speed twin roll caster, the strip did not stick to the roll due to the low rolling load and the use of the copper roll. Lubricant is not required in high-speed twin roll caster.

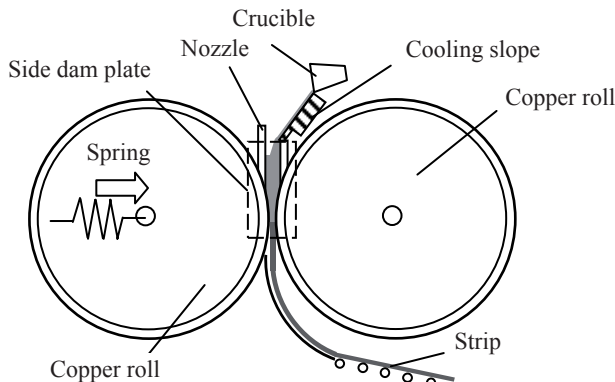


Fig.1. Schematic illustration of vertical type high-speed twin roll caster

A cooling slope was mounted on the high-speed twin roll caster in order to perform low superheat casting. Low superheat casting and semisolid casting have several advantages, including an increase in the cooling rate of the strip and an increase in casting speed.

The nozzle of the high-speed twin roll caster is assembled from four plates, including two side dam plates and two nozzle plates, the nozzle plates being moveable. A puddle is formed in

the space between the four plates. The nozzle of the high-speed twin roll caster is simple and adjustable. The solidification length can be controlled by the position of the nozzle.

Experimental conditions are shown in table 1. 6016 that is a kind of Al-Mg-Si aluminum alloys were used. Low superheat casting was performed to increase cooling rate. The superheat of the melt poured from crucible was about 5°C. Lubricant was not used. Casting speed was 60 m/min. Tensile test and 180 degrees bending test were operated to investigate the mechanical properties. Microstructures of as-cast strip and T4 treatment condition were observed.

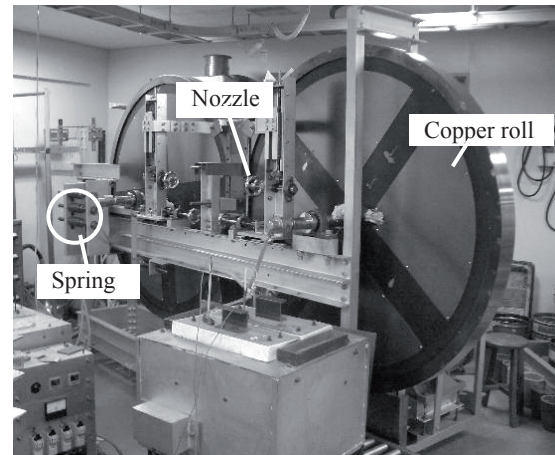


Fig. 2. The photograph of the vertical type high-speed twin roll caster

Table 1. Experimental condition

Roll material	Copper
size	Diameter 1500 [mm], width 100 [mm]
speed	60[m/min]
aluminum alloy	6016
superheat	5[°C] (pouring)
Cooling slope	
Material	Mild steel
Size	length 300 [mm], width 100[mm]
inclination angle	45 [degrees]
Separating force	0.14 [kN/mm]
Solidification length	180[mm]
Melt head	100 [mm]

3. Result and discussions

3.1. Surface of strip

Figure 2 shows photograph of the vertical type high-speed twin roll caster. 6016 could be cast to the strip continuously at a speed of 60 m/min. No lubricant was applied, and the strip did not stick to the roll. The twin roll caster of the present study was able

to cast at speed 10 times higher than that of the conventional twin-roll caster. Figure 3(a) shows surface of as-cast strip. There was no ripple mark on the surface of the strip. There were parts became cloudy in white. There were patterns rubbed with the tip of the nozzle. There was no difference on both sides of the strip. The contact condition between the melt and the roll is worse at the part of cloudy in white than at other areas. The thickness of the strip was about 3.4 mm. Figure 4 shows thickness distribution of direction in width of the as-cast strip. The shape of the as-cast thickness distribution is concave. The thickness of center of width was 0.3mm thinner than the edge of the strip. The cause of this non-uniformity is heat distribution on roll surface. Figure 3(b) shows surface of the strip after cold rolling. It's could be cold-rolled without homogenization to 1mm. The surface and non-uniformity of thickness distribution was improved by the cold rolling at the reduction higher than 20%.

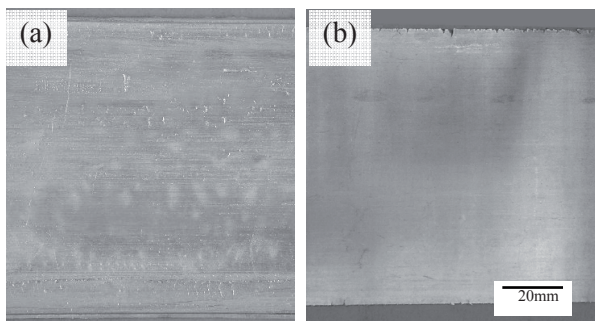


Fig. 3. Surface of 6016 strip. (a): As cast, (b): Cold rolled

3.2. Microstructure of strip

The microstructure of the strips cast by the conventional twin-roll caster for aluminum alloy is usually columnar structure. Figure 5 shows the microstructure of 6016 strip by the twin roll caster of the present study. The microstructure of as-cast strip was not uniform at thickness direction. The microstructure of center area was near to grainy or spherical structure, and the near surface was near to equiaxed structure. Figure 6 shows microstructure of 6016 ingot cast by the insulator mold. The microstructure of 6016

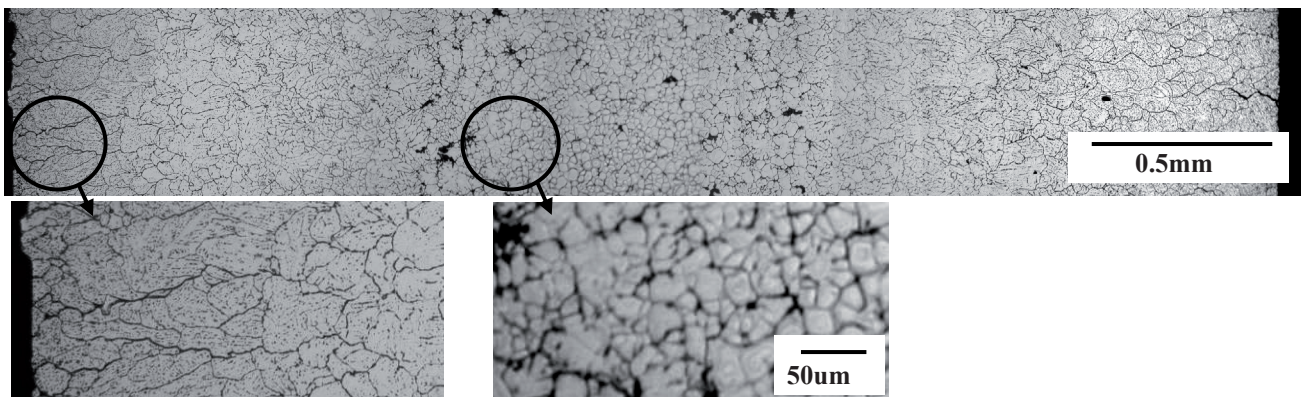


Fig. 5. Microstructure of cross section of as-cast strip

strip by the twin roll caster of the present study was smaller than the microstructure of insulator mold casting. This is the effect of rapid solidification by the twin roll caster of the present study. Figure 7 shows the microstructure of the strip after cold rolling and T4 heat treatment. This non-uniformity of the microstructure became almost uniform after the cold rolling and T4 heat treatment.

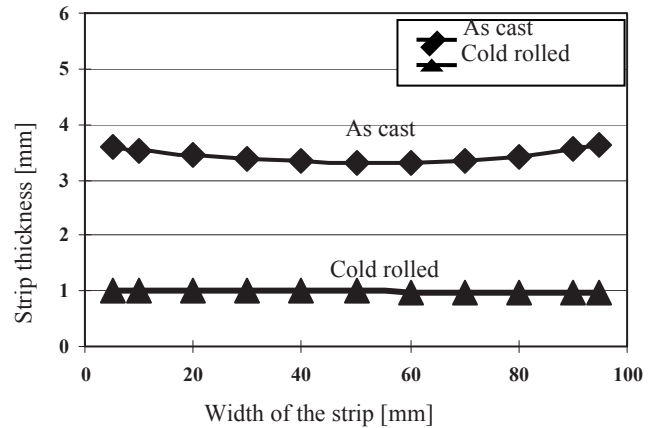


Fig. 4. Thickness distribution in the lateral direction of as-cast strip and cold-rolled strip

3.3. Mechanical properties

Table 2 shows mechanical properties of the 6016 strip. The thickness of the test piece for tensile test was 1 mm. T4 heat treatment was performed the test piece. Tensile strength is 230MPa, 0.2% proof stress is 118MPa, and elongation is 33%. The test piece for 180 degrees bending test was made from same as that for the tensile testing. The thickness of the test piece was 1 mm, and bending was carried out T4 heat treatments. Figure 8 shows the surface and cross section of 180 degrees bending test. When heat treatment was T4, there was no crack on the outer surface, and the strip was not broken. The 6016 showed good ductility by the rapid solidification of high-speed roll casting.

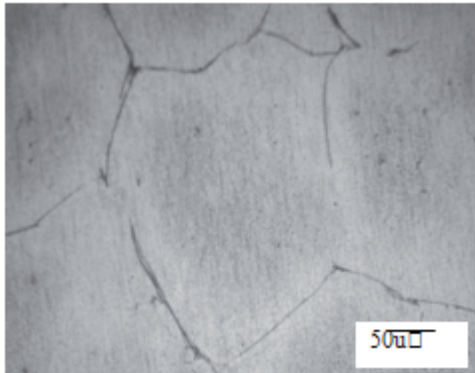


Fig. 6. Microstructure of 6016 by insulator mold

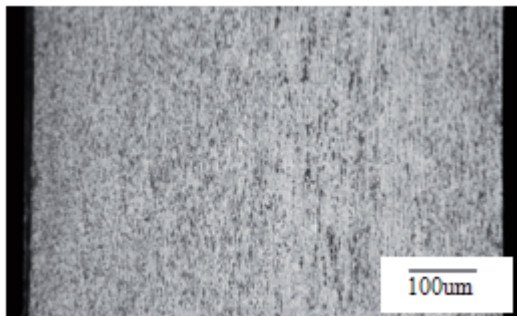


Fig. 7. Microstructure of cross section of 6016 strip at T4 condition. Treatment: cast, cold rolling down to 1 mm, T4 heat treatment

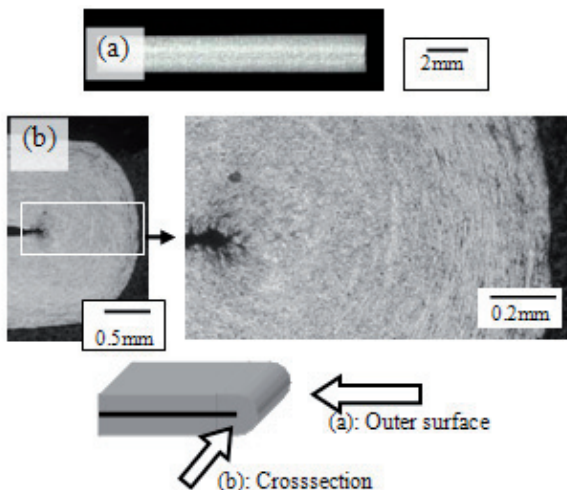


Fig. 8 Result of 180 degrees bending test of 6016 strip. (a): Outer surface, (b): Cross section

Table 2.

Result of tensile test ($t=1$)

Tensile stress [MPa]	0.2% proof stress [MPa]	Elongation [%]
230	118	33

4. Conclusions

Several devices were adopted to realize rapid solidification of the strip. A high-speed twin-roll caster was designed and used in order to increase casting speeds. 6016 could be cast to the strip continuously at a speed of 60 m/min. Strip thickness was 3.4 mm. The microstructure of the strip was not columnar, but near to grainy or spherical structure. Result of tensile test was tensile strength is 230MPa, 0.2% proof stress is 118MPa, and elongation is 33%. When 180 degrees bending test at T4 heat treatment, there was no crack on the outer surface, and the strip was not broken.

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