Archives of Materials Science and Engineering

Volume 31
Issue 1
May 2008
Pages 49-52

International Scientific Journal
published monthly by the
World Academy of Materials
and Manufacturing Engineering

High speed twin roll casting of 6061 alloy strips

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Received 01.02.2008; published in revised form 01.05.2008

ABSTRACT

Purpose: of this paper is to clear the possibility of high speed roll casting of thin strips of two aluminum alloys: 6061 and recycled 6061. Mechanical properties of the roll cast 6061 and recycled 6061 strips were investigated in the frame of this purpose.

Design/methodology/approach: Methods used in the present study were high speed twin roll caster and low temperature casting. These methods were used to realize rapid solidification and increase the casting speed.

Findings: are that 6061 and recycled 6061 could be cast at speed of 60 m/min. Casted strips were about 3 mm thick. As cast strip could be cold-rolled down to sheet of 1 mm thick. 180 degrees bending test was operated on the sheet after T4 heat treatment and crack was not worse than 6022 which is typical aluminum alloy for sheet of the automobile. This result means the roll cast 6061 can be used as a sheet for body of the automobile instead of 6022.

Research limitations/implications: Research limitation is that the width of the strip was 100 mm and investigation of the properties were enough for practical use. Wider strip must be cast using the twin roll caster of the size for production.

Originality/value: The economy sheet of the 6061 for the auto mobile can be produced by the high speed twin roll caster. 6061 is typical wrought aluminum alloy of 6000 series. Therefore, the sheet of 6061 will become economy. 6061 can be recycled at two times when the 6061 is cast into strip by the high speed roll casting.

Keywords: Casting; Twin roll caster; Body-sheet; Recycle

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

The reduction of the weight of the automobile is very important problem to be solved immediately from the view point of the environment of the earth. The use of the aluminum alloys instead of steel is the most useful way to solve this problem. Aluminum alloy sheet for the body of the automobile is very expensive. The low cost of the aluminum alloy sheet must be realized. There are two ways to decrease the cost of aluminum alloy sheet. One is adoption of economy process like a twin roll caster[1-12]. The other is use of economy aluminum alloy. 6016 and 6022 are typical aluminum alloys for sheet of the body of the auto mobile. Aluminum alloys 6016 and 6022 are very expensive. The reason for this it is the limitation of impurities. The Fe content is limited lower than 0.2 mass%. When the Fe content is larger than 0.2 mass%, ductility of the sheet becomes worse. The crystallization of the intermetallic involves the Fe make the ductility of the sheet worse. 6061 is general wrought aluminum alloy. For example, 6061 is used for forging and extrusion. The limitation of Fe of 6061 is 0.7 mass% in the standard. The Fe content in 6061 is usually about 0.3 mass%, and this content is larger than that of 6022. There is possibility that the ductility of the 6061 becomes better by the high speed roll casting. If the

ductility of 6061 is improved, 6061 may be able to be used instead of 6016 and 6022. The size of the intermetallic involves Fe affects the ductility. The bad effect of the intermetallic becomes less when the size of the intermetallic of the impurity becomes small. The rapid solidification is useful to make intermetallic of impurity small. The twin roll caster has the ability of the rapid solidification. This ability is suitable for the casting of 6061. The cooling rate of the D.C. casting is about 5°C/s, and that of the conventional twin roll caster for aluminum alloy is about 700°C/s. The cooling rate of the high speed twin roll caster of the present study is more over [13-16]. The mechanical property becomes better as the cooling rate becomes higher. The higher cooling rate is demand for the twin roll caster to cast the strip of 6061.

The equipment cost and running cost of the twin roll caster is very economy. The twin roll caster can cast the strip directly from the molten metal. Therefore, equipment of hot rolling is not needed. The twin roll caster has the ability to make economy strip.

The roll speed of the conventional twin roll caster for aluminum alloy is usually slower than 5 m/min. The strip becomes economy as the productivity of the strip increases. This means that the sheet becomes economy as the roll speed becomes higher. The high speed twin roll caster satisfies both these demand. Therefore, the high speed twin roll caster was used in the present study.

The recycle of the aluminum alloy body is essential. The content of the Fe increases by recycle. It is said that the Fe content increases 0.2 mass% by one recycle. Fe was added general 6061 as the model of recycled 6061, and roll casting was tried in order to investigate the influence of Fe on the ductility.

There are few reports about twin roll casting of the strip of 6061 as the 6061 is wrought alloy for extrusion and forging. Castability of 6061 by the high speed twin roll caster is investigated as first step. The mechanical properties were investigated by the tension test and bending test as second step. Ability of recycled of 6061 was investigated as third step. The result of the 6061 was compared to the result of the 6022.

2. Experimental conditions

Schematic illustration of high speed twin roll caster is shown in Fig.1. The copper roll diameter was 1500 mm and the width was 100 mm. The roll speed was 60 m/min. The solidification length was 180 mm. The initial load of the roll was 14 kN. The load was operated by the spring. The cooling slope was used for low solidification rate semisolid casting [13-17]. The length of the cooling slope was 300 mm and incline angle was 45 degrees. The cooling slope was made from the mild steel and its surface was coated by BN. Aluminum alloy was melt by the electric furnace in the air. The melt was conveyed to the twin roll caster using crucible. The melt was poured into the roll gap through the cooling slope. Pouring temperature of the melt on the cooling slope was 660°C. Solid fraction of the melt flew through the cooling slope was about 5 %.

The chemical composition of the standard 6022 and 6061alloys is shown in Table 1. The chemical composition of modified 6022 and 6061 is shown in Table 2. Fe was added as the model alloy of the recycled alloy. The wire of mild steel was put into the melt to increase the Fe content. The as-cast strip was cold-rolled down to 1mm without the homogenization.

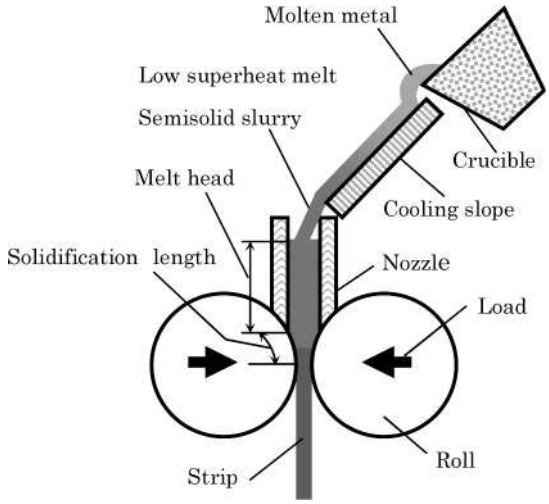

Fig. 1. High speed twin roll caster

Table 1.
Chemical composition of the standard 6022 and 6061(mass%) alloys

Alloy	Si	Mg	Fe	Cu	Mn	Ti	Al
6022	1.1	0.6	0.14	0.01	0.1	0.02	Rest
6061	0.77	1.1	0.3	0.33	0.09	0.02	rest

Table 2.
Fe content in modified 6022 and 6061 as the model of recycled aluminum alloy

Base metal	Fe content (mass%)
6022	0.45, 0.6, 0.75
6061	0.7

The T4 heat treatment was operated on the cold-rolled strip. T4 condition is as below. Cold rolled strip was kept at 530°C for one hour, and it was water-quenched immediately. 180 degrees bending test was operated on the T4 heat treated strip. 5 % of strain was induced to the T4 heat-treated strip before the bending. Crack at the outer surface of the bent strip was investigated. Tension test was operated on T4 strip, too.

3. Results and discussion

3.1. Roll casting of 6061 and Fe added 6061

6061 alloy could be cast into the strip continuously using the high speed twin roll caster. Figure 2 shows the casting in operation of the high speed twin roll caster. There was not difference in casting between the 6022 strip and 6061 strip. The strip thickness was 3.4 mm. Fe added 6061 (modified 6061) could be cast into the strip continuously, too. The casting became better when Fe content increased. This reason is that the flow ability at semisolid condition became better as the Fe content increased.

Fig. 2. Roll caster in operation. A high speed twin roll caster equipped with 1500 mm diameter rolls

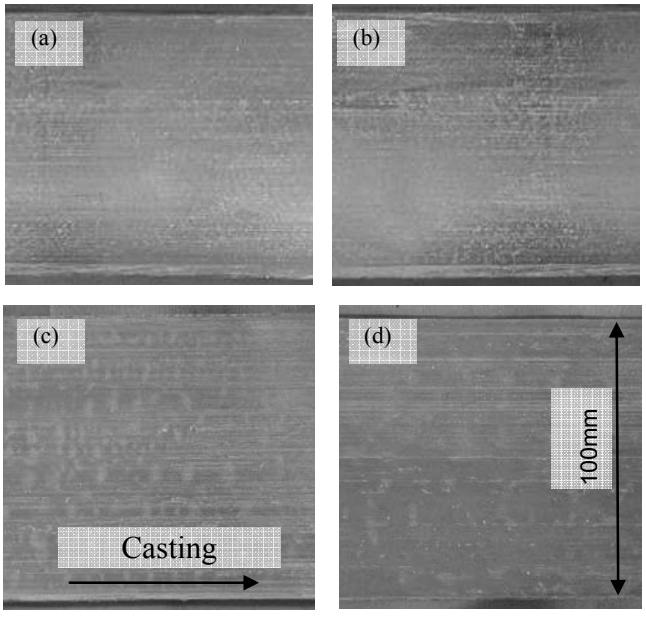

Fig. 3. Surface of as cast strip. (a) standard 6061 (Fe: 0.3 %), (b) Fe added 6061 (Fe: 0.7 %), (c) standard 6022 (Fe: 0.14 %), (d) Fe added 6022 (Fe: 0.75 %)

Figure 3 shows the surface of the as-cast strip. There was not apparent difference between the 6022 strip and 6061 strip. Increase of the Fe content did not affected the surface. The strip was free from nipple mark which is typical surface defect of the roll-cast strip. These strips could be cold rolled down to 1 mm, and the surface condition was improved as shown in Fig. 4. The surface of the cold rolled strip had metallic luster.

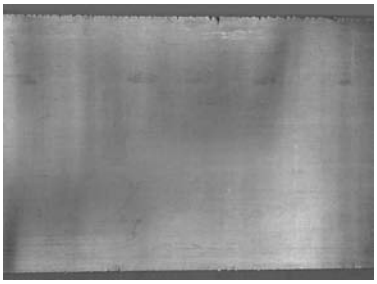

Fig. 4. Strip surface after cold rolling

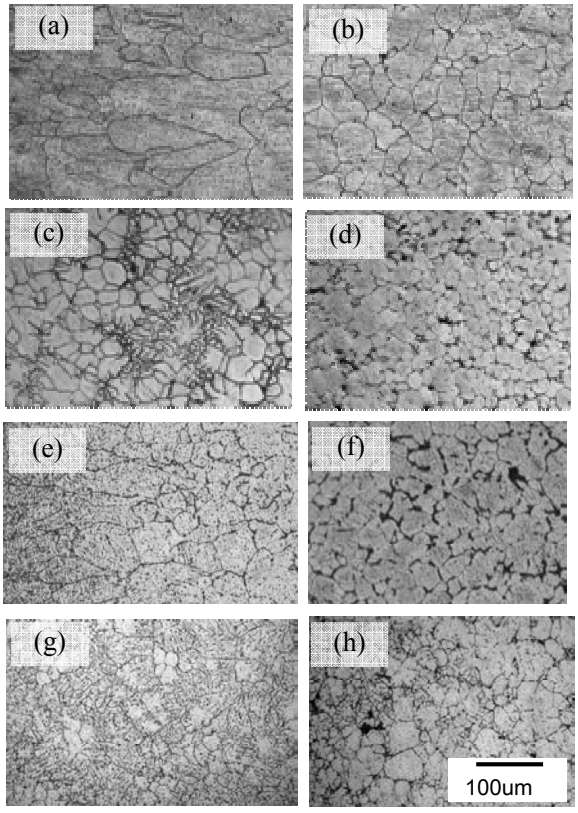

Fig. 5. Microstructure of the cross section of as-cast strip. (a), (c), (e) and (g) are the position of near surface. (b), (d), (f) and (h) are middle at thickness direction. (a), (b): standard 6061(Fe: 0.3 %), (c), (d): Fe added 6061 (Fe:0.7 %), (e), (f): standard 6022 (Fe: 0.14 %), (g), (h): Fe added 6022 (Fe: 0.75 %)

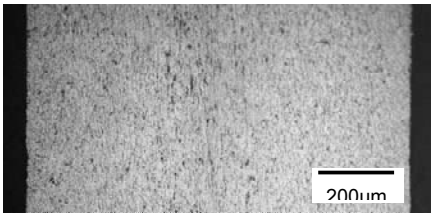

Fig. 6. Microstructure of the crosssection of 6061 strip after cold rolling and T4 heat treatment

Figure 5 shows microstructure of the cross section of the strip. The microstructure of the near surface and middle of thickness direction are shown. The microstructure was not uniform at thickness direction. This is the effect of the difference of the cooling rate at thickness direction. The primary crystal became spherical, which is the typical microstructure of the semisolid casting, at the middle of the thickness direction. When the cold rolling and T4 heat treatment was operated on the as-cast strip, the microstructure became uniform as shown in Fig.6.

3.2. Mechanical properties

The mechanical properties of roll cast 6061 were investigated by the 180 degrees bending test and tension test. The result of the bending test was shown in Fig. 7. Crack did not occur at standard 6061 as shown in Fig. 7 (a). When the Fe content was 7 mass %, crack occurred but strip was not broken. The result of 6061 at 0.7 mass % Fe was better than the result of 6022 at 0.75 mass %Fe. Si content of 6061 is less than that of 6022. Therefore, the intremetallic including Si and Fe of 6061 was less than that of 6022. Therefore, the result of bending test of 6061 became better than that of 6022.

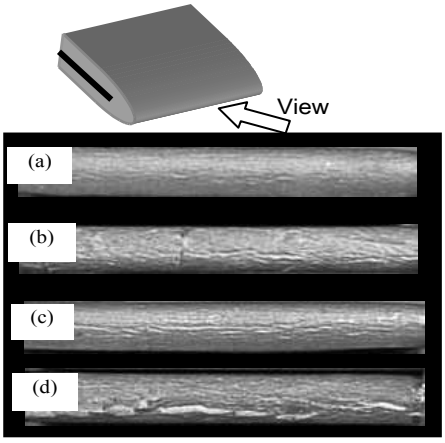

Fig. 7. Result of the 180 degrees bending test. (a) standard 6061 (Fe: 0.3%), (b) Fe added 6061 (Fe:0.7%), (c) standard 6022 (Fe: 0.14%), (d) Fe added 6022 (Fe: 0.75%)

Table 3.
Results of the tension test

Fe content	Tensile stress [MPa]	Proof stress [MPa]	Elongation [%]
6061(0.3%)	188	84	27
6061(0.7%)	208	99	23

Result of tension test was shown in Table 3. The elongation of 6022 at 0.7 mass % Fe attained at 23%. The result of bending test and tension test shows that general 6061 and recycled 6061 has ability to be used as the body sheet of auto mobile.

4. Conclusions

6061 alloy strip cast by a high speed twin roll caster had ability that they could be used as the sheet metal for the automobile, instead of 6022 alloy strips. Ductility of two times recycled 6061 alloy strip cast by the high speed twin roll caster decreased down to 23 % However, this ductility might be enough for the sheet of the auto mobile.

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