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# 論文 / 著書情報
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（博士課程）
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# 論 文 要 旨
THESIS SUMMARY

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要旨（英文 800 語程度）Thesis Summary（approx.800 English Words ）


Al-Mn based alloys with high Mn content are expected to have improved mechanical properties due to solid solution hardening and/or dispersion hardening. However, it is difficult to increase the level of Mn supersaturation in cast products using conventional DC casting. To solve this problem, the present study focused on the vertical-type high-speed twin-roll casting (HSTRC), which is characterized by a high cooling rate. The potential use of HSTRC for fabricating high manganese-containing Al-Mn-Si alloy strips was investigated. The solidification manner and the resultant microstructure were also discussed. The high level of Mn supersaturation was effectively used to enhance the strength of subsequent cold-rolled and annealed sheets, which were collected from cast strips. The influence of Mn and Si contents on the strength and the strengthening mechanism of the sheets were also examined.

The present thesis entitled "Microstructure of high-manganese Al-Mn based alloy strips fabricated by high-speed twin-roll casting and mechanical properties of their cold-rolled sheets" consists of six chapters. The summary of each chapter is described as follows.

In chapter 1, "General introduction", the general introduction of aluminum alloys and aluminum-manganese system was introduced. Previous research on high Mn-containing alloys, the importance of HSTRC to produce the alloys and dispersion hardening effect in the alloys were briefly reviewed. The goals of the present research and the construction of this thesis were presented.

In chapter 2, "Microstructure of Al-Mn-Si based alloy strip fabricated by high-speed twin-roll castings", HSTRC was used to fabricate Al-Mn-Si alloy strip. The characteristic microstructure of the cast strip was examined with the help of Weck's reagent. The microstructure of the strips consisted of two main components: the solidified shell in the surface region and the central band in the mid-thickness region. The solidified shell was composed of cellular and equiaxed dendrites, while the central band had many globular grains. A colorful microstructure was observed by Weck's etching and a doughnut-like or necklace-like patterns (core structure) were visualized inside some globular grains. They were named Type-I globular grains for comparison of the other type with no core structure (Type-II). The high correlation of obtained color and micro-segregation of Si was revealed by SEM-EDS analysis of Type-I grains. Based on the microstructure observation, the origin of globular grains observed in the central band in HSTRC strip was discussed in detail. Type-I grains were observed in both central band and the solidified shell in sub-surface region. It is considered that the origin of Type-I grains is the floating crystals, which nucleated in the melt pool or on the roll surface. Some crystals are trapped in the solidifying shells from both roll surface, and most of them are sandwiched between the solid growth fronts at the roll gap to form the central band. Type-II grains were observed only in the central band. They are originated from the twiggy dendrite branches broken at the location near the minimum roll gap. They grow to globular gains in the final solidification region, i.e., in the central band.

In chapter 3, "Fabrication of high Mn containing Al-Mn-Si strips by HSTRC, and the mechanical properties of their cold-rolled sheets", a fabrication of high Mn-containing Al-Mn-Si alloy strips using HSTRC was carried out. The alloys containing maximum of 4wt% Mn and 2wt% Si were successfully cast into strips. The solidified structure of the cast strips consisted of three layers. Two solidified shells with a columnar dendrite structure grew from the roll surfaces toward the strip center. In the mid-thickness region, the band structure consisting of equiaxed dendrites and globular grains was observed between the solidified shells. Fine secondary particles were observed in the matrix near the strip surface, while relatively coarse particles with blocky-liked and needle-liked shapes

were observed in the central band of the cast strips. The cast strips show a considerably high level of Mn supersaturation. The highest Mn concentration in supersaturated solid solution was estimated in the 4wt% containing strips at about 2.26wt%. A large cold-rolling reduction rate was directly applied to the cast strips, and 0.1mm-thick thin sheets were obtained from the cast strips. The stress-strain responses of the cold-rolled and annealed sheets were like those of precipitation-hardened alloys. This behavior is considered to result from the precipitation of uniformly distributed very fine dispersoids by annealing at 400°C for 24h. The sheets collected from HSTRC strips show a superior mechanical strength to the conventional non-heat-treatable 3000 and 5000 aluminum alloys.

In chapter 4, "Effect of large particles in the central region of Al-4Mn-1Si HSTRC cast strip on elongation of subsequent cold-rolled and annealed sheet", the formation of coarse particles in the central band of Al-4wt%Mn-1wt%Si strips and the effect of these particles on elongation of subsequent cold-rolled and annealed sheets were thoroughly investigated. Microstructure and chemical analyses revealed that the coarse particles are $Al_6Mn$ and β-AlMnSi. These particles are considered to be formed in the solidification process of the residual liquid, which were slowly cooled after the strip left from the roll gap during HSTRC. Extra cooling by blowing the compressed air to the strip surface immediately after the strip left the roll gap effectively reduced the number and size of these particles in the central band. The refinement of particles in the central band of the as-cast strip resulted in the refined and homogenous microstructure without coarse particles of the cold-rolled and annealed sheets. Consequently, improvement of both strength and elongation was achieved successfully.

In chapter 5, "Influence of high Mn and Si on dispersion hardening effect in the cold-rolled and annealed sheets collected from HSTRC cast strips", the strips containing 2 to 4wt% Mn and 1 to 2wt% Si were fabricated by HSTRC. The influence of Mn and Si on the solidified microstructure of the cast strips was studied. As increasing Mn content, denser distribution of constituent particles was observed in the near-surface region while many coarse particles were observed in the central part. As increasing Si content, constituent particles distributed in near-surface regions became denser, and the change of particles' morphology was observed in the central area. A high level of Mn supersaturation of about 2.2wt% was achieved in the cast strips. The cast strips were cold-rolled to 0.1mm-thickness sheets and annealed at 400°C for 24h. The quantitative analysis of constituent particles and dispersoids in as-rolled and annealed conditions was performed. The influence of Mn and Si on the precipitation of dispersoids was discussed from the distribution manner of constituent particles. The original microstructure in the as-cast condition controlled the distribution of constituent particles in the as-rolled condition. The dense distribution of very fine dispersoids was obtained under the state with the sparser distribution and larger interspacing of constituent particles. The dispersion hardening effect of dispersoids was explained by the Orowan bowing mechanism. The overall contribution of dispersion hardening to the yield strength of the sheets was enhanced as increasing Mn content, while it was decreased as increasing Si content. A significant dispersion hardening effect was achieved in the sheets collected from HSTRC strips with high level Mn supersaturation in the as-cast condition. The most pronounced dispersion hardening effect was observed in 4M and 1S sheets.

In chapter 6, "Conclusions", the findings in the present work were summarized and conclusions of this study were provided.

The present study provided the basic information related to the microstructure and solidification behavior of new Al-Mn-Si alloy strips fabricated by HSTRC. This study also presented the potential to fabricate thin Al-Mn-Si sheets from the as-cast strips with improved mechanical strength compared to conventional 3000 aluminum alloys. The sheets obtained in this study might be promising for applications in which higher yield strength and higher strength at elevated temperature are required.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
Note：Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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