論文 / 著書情報
Article / Book Information

題目(和文)	縦型高速双ロール鋳造法により急冷凝固したAl-Mn系合金板材の微細組織
Title(English)	Microstructure of rapidly solidified Al-Mn based alloy strips fabricated by vertical-type high-speed twin-roll casting
著者(和文)	SongRam
Author(English)	Ram Song
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11084号, 授与年月日:2019年3月26日, 学位の種別:課程博士, 審査員:熊井 真次,村右 信二,中村 吉男,小林 能直,小林 郁夫
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11084号, Conferred date:2019/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	材料工学　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（ 工学 ）
学生氏名： Student's Name	宋　濫	指導教員（主）： Academic Supervisor(main)	熊井　真次
		指導教員（副）： Academic Supervisor(sub)	村石　信二

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

The wrought non-heat treatable Al-Mn based alloys have been widely used in diverse applications such as fin of automotive heat exchanger and thin sheets for beverage can body due to their moderate strength and good workability. The wrought Al-Mn based alloys have been fabricated conventionally by direct chill (DC)-casting followed thermo-mechanical processes *e.g.* homogenization, hot- and cold rolling. The downstream processes after the casting result in high production cost and large energy consumption. Also, the DC-casting is conducted at low cooling rates resulting in not only low Mn solubility that unfavorable to the formation of fine dispersoids by the given successive heat treatment, but also forming coarse constituent particles in as-cast condition. In order to avoid these disadvantages, vertical-type high-speed twin-roll casting (HSTRC) is proposed in the present study. The HSTRC can produce a thin metal strip directly from the melt with a remarkable high casting speed. As a result, subsequent hot rolling process can be eliminated. In terms of Al-Mn based alloys, high cooling rate of the HSTRC can expand Mn supersaturation and promote refined secondary particles as well as their homogeneous distribution. Hence, the HSTRC has a high potential to control the microstructure and improve final mechanical properties of Al-Mn based alloys. A better understanding of the solidification structure of HSTRC processed strips is crucial to the optimization of the downstream processes and mechanical properties of the Al-Mn based alloys. The purpose of the present study is to obtain basic and precise information concerning the microstructure of rapidly solidified Al-Mn based alloy strips fabricated by HSTRC. This thesis consists of 7 chapters. Detailed content of each chapter is described as below.

In Chapter 1, “General introduction”, general characteristics and application fields of the wrought Al-Mn based alloys were briefly reviewed, and DC-casting, horizontal-type twin-roll casting, and the HSTRC were introduced. The objective of the present study and the outline of this thesis were also described.

In Chapter 2, “Solidification structure and secondary particles in vertical-type high-speed twin-roll cast 3003 aluminum alloy strip”, commercial 3003 aluminum alloy strip was fabricated by HSTRC, then solidification structure and secondary particles were investigated. Refinement of both the solidification structure and secondary particles were achieved in the 3003 aluminum alloy strip. The 3003 aluminum alloy strip consisted of cell structure, dendrite structure, globular grains and eutectic structure along the strip thickness direction. Significant differences in the formation of secondary particles were found between DC-casting and the HSTRC as a result of the different cooling rates; orthorhombic $Al_6(Mn,Fe)$ phase was the main secondary phase in DC-cast sample, whereas only cubic α-Al(Mn,Fe)Si phase was predominant secondary phase in HSTRC processed strip. This resulted in the increase of solute segregation in liquid phase, particularly Si content, during solidification due to the high cooling rate of the HSTRC.

In Chapter 3, “Influence of alloying elements on solidification structure of vertical-type high-speed twin-roll cast Al-Mn based alloy strips”, the influence of alloy composition on solidification structure in Al-Mn based alloy strips fabricated by HSTRC was investigated in this chapter. As major alloying elements, Mn, Fe and Si elements were selected. Binary Al-Mn,

ternary Al-Mn-(Fe,Si), and quaternary Al-Mn-Fe-Si alloys were prepared, then grain structure and kinds, distribution of secondary particles in each alloy strip were investigated. The solidification structure of the strips was related with their alloy compositions; skin-type solidification structure in binary Al-Mn alloy strip, and mushy-type solidification structure in ternary Al-Mn-(Fe,Si) and quaternary Al-Mn-Fe-Si alloy strip, respectively. Increasing a freezing temperature range of the alloys resulted in the formation of free-crystallized α-Al grains in the melt. The free-crystallized α-Al grains gather at the strip central area that can lead to increase stable strip thickness.

In Chapter 4, “Influence of cooling rates on formation behavior of secondary particles in vertical-type high-speed twin-roll cast Al-Mn based alloy strips”, the formation of secondary particles in the strips was investigated more precisely for ternary Al-Mn-Fe and Al-Mn-Si alloys. Influence of cooling rates on secondary particle formation was studied based on the comparison of various cooling rate conditions; furnace cooling, DC-casting, HSTRC and single-roll casting. Increase in cooling rates resulted in decrease of Mn composition ratio and enrichment of Fe and Si composition ratio in secondary particles.

In Chapter 5, “Mn supersaturation and solid solution strengthening in vertical-type high-speed twin-roll cast Al-Mn binary alloy strips”, it was focused on the Mn supersaturation in high-speed twin-roll cast Al-Mn binary alloy strip. The Al-Mn binary alloy strips with various Mn compositions were fabricated by using the HSTRC. High level of Mn supersaturation could be achieved by high cooling rate of HSTRC. Applying the sufficient melt superheating was effective to prevent formation of primary Al_6Mn particles and to increase the Mn concentration in Al matrix. Significant increase in yield strength was obtained in the high Mn supersaturated Al-Mn binary alloy strip. It was mainly attributed to contribution of Mn solid solution strengthening.

In Chapter 6, “Solute distribution and Mn decomposition behavior in vertical-type high-speed twin-roll cast Al-Mn based alloy strips”, the solute distribution and Mn decomposition behavior, which have a strong influence on secondary particles formation in high-speed twin-roll cast Al-Mn binary, Al-Mn-Fe and Al-Mn-Si ternary alloy strips were investigated. The high cooling rate of HSTRC resulted in homogeneous distribution of solute atoms and secondary particles. The Fe and Si enhanced the Mn decomposition during homogenization. In the Al-Mn-Fe ternary alloy strip, constituent particles of Al_6(Mn,Fe) phase were homogeneously distributed in the as-cast strip due to the high cooling rate. The Mn decomposition mainly occurred by the diffusion of Mn toward the constituent particles resulting in increase of Mn composition ratio in the constituent particles and their spheroidizing and coarsening during homogenization. In the Al-Mn-Si ternary alloy strip, formation of fine α-AlMnSi dispersoids was predominant way for the Mn decomposition during homogenization. The distribution of dispersiods was well corresponded to the solute distribution within Al matrix especially Si element. Due to the high cooling rate of HSTRC, homogeneous Mn and Si distribution was achieved that contributes to enhance decomposition of supersaturated Mn during homogenization in high-speed twin-roll cast strip.

In Chapter 7, “General conclusions”, the conclusions of the present thesis are provided based on the overall experimental findings and research achievements.