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Effect of casting plan and alloying content on the hot tearing of Al-Si alloy

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The effects of Si content and Sr addition on the hot tearing of Al-0%, 1%, 4%, 7%, 10% and 12.5% Si-0.3%Mg alloys were investigated using a T-shape product. Hot tearing was not observed in pure Al or in 12.5%Si-0.3%Mg alloy. The narrow solidification temperature range for the two alloys does not generate the high thermal stress that causes hot tearing. While hot tearing was observed in the 1%, 4%, 7% and 10% Si-0.3%Mg alloys, the crack length decreases with increasing Si content. The vertical bar portion of the T-shaped product is thick and undergoes delayed solidification. However, hot tearing takes place when solidification of the vertical bar portion is relatively fast. The addition of 0.1%Sr into the 7% and 10% Si-0.3%Mg alloys removes cracks with a filled eutectic phase through a healing mechanism, but the Sr addition does not heal the cracks in the 1% and 4% Si-0.3%Mg alloys.

Key words : *Hot tearing , Crack, Casting plan Sr addition, Thermal stress*

1. Introduction

JIS-AC4C alloy (Al-7%Si-0.3%Mg) is widely used for automotive components because of its superior castability. However, we found that hot tearing takes place when a particular casting plan is chosen. We designed four casting plans for a T-shape product and experimentally compared the influence of the casting plan on the hot tearing. It was found that the casting plan without a gate and runner, in particular, triggers hot tearing at the crossing corner portions between the horizontal bar and the vertical bar of the T-shape [1]. An elastic finite element method (FEM) stress analysis combined with a casting and solidification simulation revealed that high tensile stress causes hot tearing at the corners [2]. The high stress is generated by the temperature distribution associated with the T-shape. Hot tearing appears when the ratio of the solidification time for the vertical bar [ta] to that for the horizontal bar [tb] is less than 1.5. Also, it was found that a higher Sr concentration than 0.003% restricts the hot tearing by a healing process [3]. Based on previous research on the AC4C alloy, the purpose of this study was to investigate the effects of Si content and Sr addition on the hot tearing of Al-0% to 12.5% Si-0.3%Mg alloys.

2. Experimental procedures

A casting test was conducted using a top-pouring casting plan for the T-shaped product (**Fig. 1**). The casting plan without a gate and runner showed hot tearing in the AC4C alloy [1]

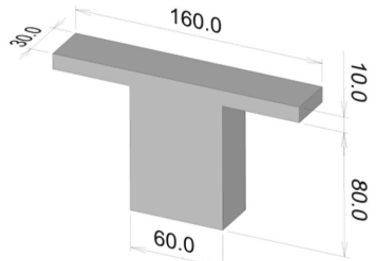

Fig.1 The casting plan.

A new silica sand mold was prepared with the addition of a 2% resin and a 0.4% curing agent. Al-0% to 12.5% Si-0.3%Mg alloys were used. Gas bubbling filtration (GBF) degassing reduced the hydrogen content to 0.2 cc/100 g Al. To investigate the effect of Sr, 0.01% Sr was added just before pouring. ADSTEFAN Ver. 2013 was used for the casting and solidification analysis. The parameters for the analysis were taken from the experimental conditions. The elastic FEM stress analysis using ANSYS Workbench 4.0 was used to calculate the stress distribution in the product.

3. Result and Discussion

Fig. 2 shows the cooling curves observed at three positions (horizontal bar, vertical bar and corner) in the 4%Si-0.3%Mg product. Solidification starts from the horizontal bar and proceeds through the corner to the vertical bar. The order was roughly the same regardless of the Si content of the alloys.**Fig. 3** shows the effects of Si content and Sr addition on the crack length. Pure Al and 12.5%Si-0.3%Mg alloy do not show any hot tearing. It was thought that the narrow solidification temperature range for the two alloys

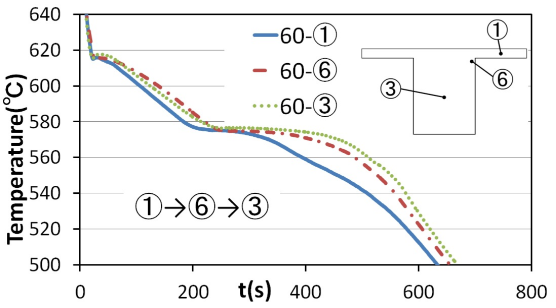

Fig.2 Cooling curves at the horizontal bar, vertical bar and corner.

does not generate the high stress that causes hot tearing. With increasing Si content, the crack length decreases. High stress is generated by the temperature distribution when the ratio (ta/tb) of the solidification time for the vertical bar (ta) to that for the horizontal bar (tb) is below 1.5. Fig. 3 also includes ta/tb lines. It is observed that the crack length decreases with increasing ta/tb. A ratio of unity indicates homogeneous solidification. If the thick vertical portion of the T-shape solidifies quickly when the corner portion is in the semi-solid state, the quick solidification generates high thermal stress on the crossing corner portions.

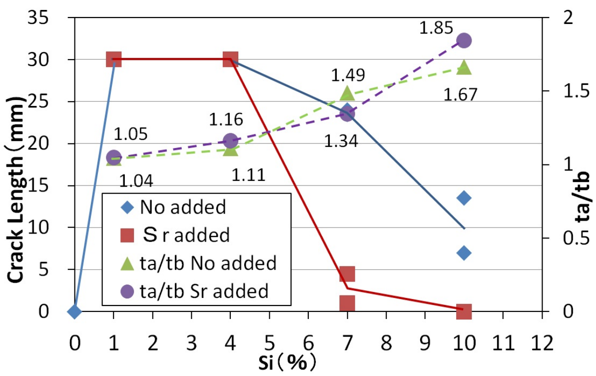

Fig.3 Effects of Si content and Sr addition on the crack length and ta/tb.

The addition of Sr into 7% and 10% Si-0.3%Mg alloys restricts cracking. However, even with the addition of Sr, hot tearing occurs in 1% and 4% Si-0.3%Mg alloys.

Fig. 4 shows the corner microstructures of 1%, 7% and 10% Si-0.3%Mg alloys with and without Sr. The Sr addition to the 7% and 10% Si-0.3%Mg alloys removed cracks through a healing process. However, the Sr addition to the 1%Si-0.3%Mg alloys did not remove cracks. It was thought that the Sr addition increases the permeability of the eutectic phase through a channel between the dendrites and enhances the healing of the alloys due to the higher amount of the eutectic phase.

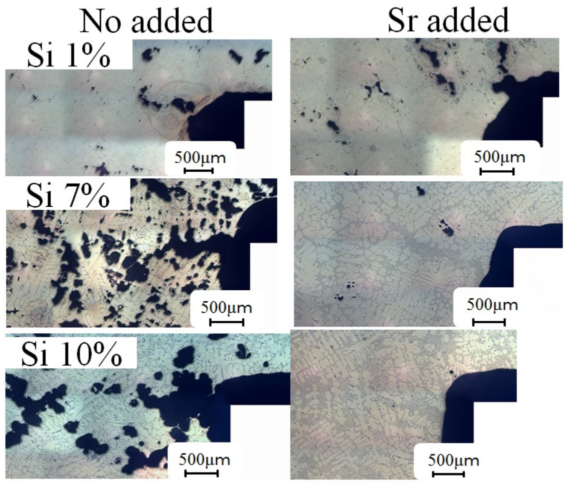

Fig. 4 Corner microstructure of Al-1%, 7% and 10%Si-Mg alloys with and without Sr.

4. Conclusion

The effects of Si content and Sr addition on the hot tearing of Al-0%, 1%, 4%, 7%, 10% and 12.5% Si-0.3%Mg alloys were investigated. The effects are summarized as follows.

(1) Hot tearing was not observed in pure Al and in Al-12.5%Si-0.3%Mg alloy. The narrow solidification temperature range does not generate a high thermal stress and restricts hot tearing.

(2) With decreasing Si content, the crack length increases. The solidification at the vertical bar portion of the T-shape will likely be delayed. Hot tearing occurs in the alloys when the solidification at the vertical bar portion is relatively fast and generates high tensile stress at the corner portion.

(3) The Sr addition into Al-7% and 10% Si-0.3%Mg alloys restricts cracking through a healing process, but it does not restrict hot tearing of Al-1% and 4% Si-0.3%Mg alloys. The healing is controlled by the amount of the eutectic phase and Sr itself.

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