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Short Communication

Effect of grain refinement on the microstructure and tensile properties of thin 319 Al castings

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ABSTRACT

The structural examinations and tensile properties of thin-section Al castings (319 Al alloy) have been investigated by applying a pattern with different cross sections (2–12 mm). Al–5Ti–1B and Al–5Zr grain refiners were added to the molten Al alloy to produce different levels of Ti (0.01%, 0.05%, 0.1% and 0.15%) and Zr (0.05%, 0.1%, 0.2%, 0.3%, 0.4% and 0.5%) in the castings. From macrostructural studies, it was found that Al–5Zr is less effective in grain refining of 319 alloy in comparison with Al–5Ti–1B master alloy. The optimum levels of grain refiners were selected for determination of tensile properties. T6 heat treatment was applied for selected specimens before tensile testing. Further structural results also showed that thinner sections are less affected by grain refiners. This observation was found to be in a good agreement with tensile test results, where tensile properties of the base and grain refined alloys did not show considerable differences in thinner sections (<6 mm).

1. Introduction

In recent years, the automotive industry has increasingly employed cast aluminum alloys in the production of engine components such as cylinder heads [1]. The aluminum alloy 319 is commonly used for this purpose. Its excellent castability, corrosion resistance and mechanical properties make it a popular alloy for these applications [2].

The increase in the use of this alloy demands a better understanding of its response to mechanical testing. The influence of processing parameters and microstructure features play an important role on alloy properties such as yield and tensile strength.

Copper is the main alloying element in 319 alloy and its presence leads to the formation of copper containing intermetallic such as Al_2Cu or θ-phase. This phase can solidify in two forms, block-like Al_2Cu and the finer eutectic-like ($Al + Al_2Cu$) [3].

It is well accepted that finer grain size of the Al alloy improves mechanical properties, hot tearing susceptibility and pressure tightness [4,5]. Fine structures can be achieved by different means such as fast cooling rate, heterogeneous nucleation, solute addition and melt agitation. Solute addition and heterogeneous nucleation, usually in combination, have become common industrial practices, due to their simplicity and efficiency [6].

The increase of cooling rate also refines microstructural features including SDAS, grain size, eutectic Si morphology, porosity and intermetallic phases, which may lead to substantial improvement in mechanical properties [7–12]. Samuel et al. have reported that the tensile properties of A319.2 alloy decrease with increasing SDAS [13]. They reported that in A319.2 alloy, the ultimate tensile strength and the elongation values decrease by about 20% and 80% respectively as the SDAS increases from 28 to 95 μm. However, the yield strength (YS) was observed to remain constant regardless of solidification time [13].

The main goal of this work is investigating the influence of Al–5Ti–1B and Al–5Zr grain refining agents on the structural and tensile properties of Al–6Si–3.5Cu (319) alloy in thin section castings.

2. Experimental procedure

The present study was performed on 319 aluminum alloy with a chemical composition given in Table 1. The alloy was sand-cast using a pattern, which is shown in Fig. 1. Prior to casting, the melt was treated with different amounts of the grain refiners. The added values were 0.2, 1, 2 and 3 wt.% for Al–5Ti–1B and 1, 2, 4, 6, 8 and 10 wt.% for Al–5Zr master alloy. Degassing of the molten alloy was conducted by submerging dry C_2Cl_6 containing broken tablets (0.3 wt.% of the molten alloy). Castings were cut into bars with thicknesses of 2, 4, 6, 8 and 10 mm. Metallographic specimens were taken from the end of each bar (20 mm). They were prepared using standard techniques with a final polishing stage of 0.05 μm colloidal SiO_2. In order to reveal grain morphologies, the specimens were deeply etched using Keller's reagent. Quantitative data of the structure on each specimen was determined using an optical microscope equipped with an image analysis system (Clemex Vision Pro. Ver. 3.5.025). Grain sizes of specimens were measured by Heyn intercept method.

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