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Full length article

Effect of Fe-rich intermetallics on the microstructure and mechanical properties of thixoformed A380 aluminum alloy

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ABSTRACT

The effect of α-Fe and β-Fe intermetallics concentration and morphology as well as α-Al morphology on the microstructure and mechanical properties of thixoformed and gravity cast A380 alloy was reported. The α-$Al_{15}Si_2(Fe,Mn)_3$ intermetallic particle was observed polyhedral morphology in thixoforming while it was observed Chinese script morphology in conventional gravity casting. The β-Al_5FeSi particle was solidified in the form of small plate in thixoforming while it was solidified in the form of needle-like in gravity casting at the grain boundaries of α-Al. The mechanical properties of the alloys have been enhanced by thixoforming compared with the conventional cast condition.

1. Introduction

Eutectic and near eutectic Al–Si alloys are widely used in casting industry due to superior abrasion and corrosion resistance, low thermal expansion coefficient and high strength/weight ratio [9,23]. There is an application area including components such as cylinder blocks, cylinder heads and pistons because of the features [3]. It is known that iron is the most common and harmful impurities in aluminum casting alloys. On the other hand, in pressure die casting alloys, iron is a desired element because it helps to prevent the transfer to mold of the molten alloys. Eutectic composition of Al–Si–Fe alloy is composed of about 0.8–1.1 wt% Fe. When iron is alloyed in these levels, the molten metal does not show tendency of dissolution with the steel mold. Thus, the higher iron content of the alloy reduces the solution potential for the components of the casting machine and dies [16]. Iron must be separated from molten aluminum. As it is not economical, some strategies have been developed to eliminate the negative effects of iron. The negative effects of iron are generally associated with the formation of iron-rich intermetallics during solidification [7,11]. Fe is mainly precipitated in the form of α-Fe ($Al_{15}Si_2(Fe,Mn)_3$) or β-Fe (Al_5FeSi) crystals. On the other hand, the intermetallic of iron-containing is composed in several forms. The morphology of α-Fe and β-Fe can be changed according to the solidification [18]. The iron-containing intermetallics in Al–Si alloys are both of the so-called α-phases form in Chinese script-like morphology and sometimes even as polyhedral crystals. Polyhedral version of α-Fe has a more compact and blocky form [21].

Mechanical properties of near-eutectic and eutectic Al–Si casting alloys do not only depend on the chemical composition. However, dendritic α-Al morphology and other intermetallics in the microstructures have important effects on the microstructural properties. The morphology and size of eutectic silicon, the morphology and composition of intermetallic compounds reveals a significant effect on mechanical properties. In this study, feed stock production with cooling slope casting and then semi-solid forming changed the morphology of intermetallics. Semi-solid forming process consists of basically two steps. First step is feed stock production of rosette-type microstructure and second step is the feed stock forming by pre-heating at appropriate semi-solid temperature. The process is called thixoforming. Semi-solid slurries exhibit rheological behaviors and this is called thixotropy [4–6,8]. The heating to semi-solid range accelerated the globalization of dendritic α-Al phase and also the production of uniformly distributed Fe-containing intermetallic compounds.

There are some theories about the relationship between microstructures and mechanical properties for aluminum alloys. Therefore, it is necessary to pay particular attention to examine mechanical properties considerably affected from microstructure. The aim of this search is to investigate the intermetallic compounds

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Table 1
Chemical composition of A380 alloy using in this work (%).

Si	Fe	Cu	Mn	Mo	Zn	Cr	Ni
8.163	0.972	2.987	0.170	0.144	0.737	0.0181	0.196

and mechanical properties obtained from thixoforming and conventional gravity casting.

2. Experimental procedure

In this work, A380 aluminum alloy parts were produced by semi-solid forming process. In addition, A380 aluminum alloy parts were produced by means of conventional gravity casting. The chemical composition of the alloy was shown in Table 1. The ingots obtained from cooling slope casting were thixoformed at semi-solid temperature. The cooling slope casting was carried out at a pouring temperature of 615 °C. The slope of inclined plate was 60° and the length of inclined plate was 350 mm. The required semi-solid temperature for thixoforming is 567 °C according to DSC diagram. At this temperature the suitable solid fraction (f_s) value for thixoforming is about 0.4–0.5 solid fraction [6]. The ingots with the diameter of Ø 30 mm and a length of 40 mm were adapted to induction coil for reheating in semi-solid temperature. The ingot temperature was controlled with a K-type thermocouple during heating process. The ingots were held for 5 min at semi-solid temperature of 567 °C and then thixoformed by a 20 ton hydraulic press. The thixoformed sample was shown in Fig. 1. Conventional gravity casting was carried out at 700 °C. The parts obtained from thixoforming and gravity castings were prepared metallographically for microstructural examination and etched in 0.5% HF solution. Microstructural examinations were performed by optical microscopy (OM) and scanning electron microscopy (SEM). Energy dispersive X-ray spectroscopy (EDX) was used to identify the intermetallics. Morphology of the α-Al phase and the intermetallic compounds show the difference in the specimens obtained from thixoforming and gravity casting. In order to investigate the effect of processing conditions on the mechanical properties of A380 alloy, 10 sets of samples were used for tensile tests. Dimensions of tensile specimen were 22 mm gauge length and 8 mm diameter (Fig. 2), and the specimens were tested at room temperature at a tension speed of 2 mm/min. The hardness HB of the specimens was then investigated. Hardness values represent the average value of at least 5 test results.

Fig. 1. The thixoformed sample from A380 alloy.

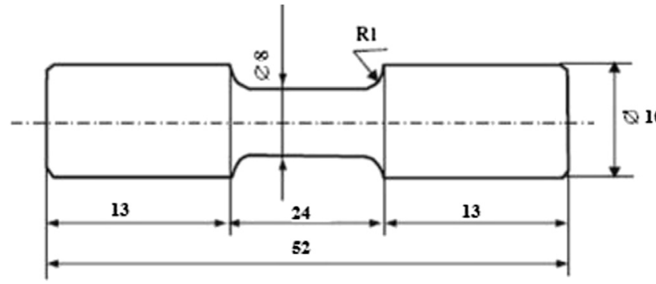

Fig. 2. Tensile test specimen.

3. Results and discussion

The microstructure of slope cast sample before thixoforming was investigated in detail by authors in the previous works [6,14]. The microstructure obtained from gravity casting in Fig. 3a has a typical dendritic structure, surrounded by a eutectic phase. Fig. 3b shows the microstructure of sample obtained from thixoforming. While α-Al grain structure has a globular form, Al–Si eutectic

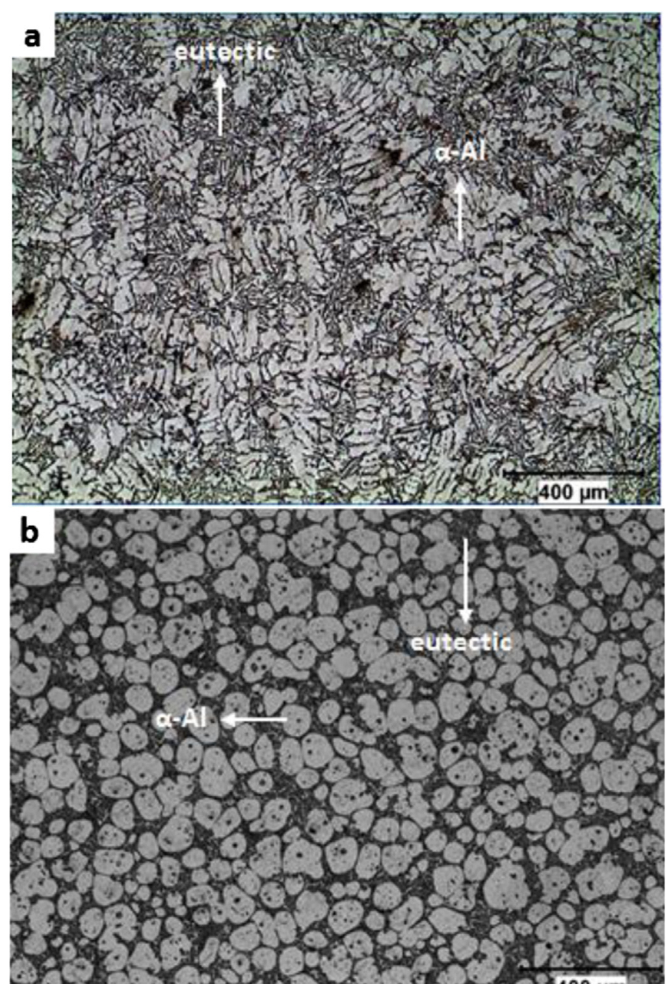

Fig. 3. The microstructure of A380 alloy obtained from (a) gravity casting and (b) thixoforming.