Study on Properties of Al-6Fe-1V-1Si Alloy

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Abstract

The paper attempts to investigate the effect of 6% iron on microstructure and mechanical properties in Al-Fe-1Si-1V cast alloys. The experimental results shows that the microstructure of cast Al-6Fe-1Si-1V alloys consist of platelet, Chinese script and star like phases. The Chinese script or star shape structure increases the stress raiser and results deterioration in properties compared to low iron bearing alloys. In order to confirm the nature of the precipitates, Scanning Electron Microscopy (SEM) has been also carried out on the cast samples. Hardness was measured in vicker's hardness testing machine and average of three readings was taken. Tensile test was measured in Universal Testing machine. From the sample test it has been found that hardness was measured 52VHN and the tensile strength was measured 119MPa for the alloys. It was clear from the results that hardness and tensile strength increases while the ductility decreases.

Keywords - Al-6Fe-1Si-1V Alloys, Microstructure, SEM Morphology, Hardness, Tensile strength

Introduction

Aluminium and its alloys are extensively used for a very wide range of application due to their light weight combined with attractive physical and mechanical properties. Therefore, these alloys motivate considerable interest to the transportation, aviation industries and other industrial applications (Prabhu, 2006; Yazdian, 2010). Al-Si alloys are mostly substituted for cast iron in automobile and engineering applications due to their superior wear resistance, low coefficient of thermal expansion, high strength to weight ratio, higher thermal stability, good corrosion resistance, high thermal conductivity, heat treatment capabilities, good machinability and excellent castability (Basavakumar, 2007).

Some Aluminum alloys like Al-Si, Al-Cu-Si and Al-Mg-Zn alloys are used in aerospace industries and transportation due to their light weight and high strength to weight ratio.

Al7075 are one of the most popular aluminium alloys (in Al7XXX series) which are widely used for aeronautical and defense applications due to their desirable mechanical properties. Besides of this, in some applications at room and elevated temperature it is observed that these alloys show weak mechanical properties such as low wear resistance etc. (Yazdian, 2010). The use of conventionally processed Al alloys is limited by their low strength at temperature above 200^0C (Das-1989). Above 200^0C temperature, the mechanical properties decrease with temperature.

Al-TM (TM - transition metal) Systems have the potential to use for high temperature. Among the Al-TM system, Al-Fe-V-Si systems have considerable interest due to its high strength at room as well as at elevated temperature (Jones, 1988). It also possesses good creep resistance, fatigue and fracture strength. In general Al-Fe-V-Si alloys are produced through rapid solidification processing (RSP) route due to low solubility of Fe and V in Al and their wide difference of densities (Sanders, 1989; Lavernia, 1992). Iron is always present in Al alloys. The solid solubility of iron in Al is very low (< 0.04 wt. %) (Mondolfo-1976). Therefore, most of the iron appears as large intermetallic phases in combination with Al and other elements. Controlling the microstructure of these precipitation-hardened alloys is very important to improve their properties. The alloys contain several alloying elements that may form different phases. These phases have been studied by a combination of various methods. (Chen, 2009) Vanadium is also added to Al alloys for its grain refining effects. It was reported that the addition of vanadium in Al-Fe-Si alloys stabilize the cubic Al_{13} $(Fe,V)_3Si$ phase [Srivastava-1988]. The cubic phase has practically less coarsening rate at temperature. Some of alloy develop by Allied Signal Company was produced by rapid solidification processing (RSP) route. In this experiment, Fe (6%), V (1%) and Si (1%) were used for the investigation in Al alloys by conventional casting method. In the present work, it is aimed at studying the effect of 6% iron in the Al alloys on its microstructure and its mechanical properties.

Experimental Procedure

Al-6Fe-1V-1Si alloys was prepared using Al 99.95% purity, Al-21% Fe, Fe-50%V and silicon about 99.99% purity in wt.%. Al-21% Fe and Fe-50%V alloys were crushed into small pieces for easy melting. The experimental alloys were prepared in an electric furnace in a graphite crucible. Degassing of the melt was done with dry Argon gas during melting. First, crucible was preheated to about 600^0C. At around 600^0C, weighted quantity of all alloys were charged. After melting, sufficient time was given for complete homogenization of the melt. The melt was frequently agitated with an iron rod for complete mixing. After degassing, the melt was cast in different moulds.

After complete homogenization at a particular temperature, the alloy was poured in mould to prepare different samples. Metallographic samples were cut from alloys and polished using belt polishing, emery paper from coarser ranges to finer one. After that, cloth polishing was done using fine alumina powder. The samples were etched with a modified Keller's reagent (2ml HF and 3ml HCl in 175ml water) for micro structural studies in an optical microscope. The microstructures of the samples were taken to distinguish the shape and size of the primary and interdendritic precipitates. The hardness from the sample was measured in Vicker's hardness testing machine. A load of 5Kg was applied for testing hardness. Average of three measurements of each as cast samples was taken. The standard Hounsfield specimens were made from the as cast samples. These specimens were tested in a Hounsfield Tensometer (tensile testing machine) at room temperature at a strain rate of 3mm/min. The Ultimate tensile strength (UTS), percentage (%) elongation and percentage (%) reduction in area were measured.

Optical Microscostructure Study

Microstructure of Al-6Fe-1V-1Si alloy is discussed in this section. The samples were cast in different moulds to check different properties. The effect of 6%Fe in Al-Fe-Si-V alloy has been reported at cooling rate 20^0C/sec. The molten metal processing techniques conventionally adopted in order to achieve proper microstructure, which provides required mechanical and physical properties in the casting, are grain refinement and modification. Influence of structure on many physical and mechanical properties is well known and therefore it can be directly related to the properties. Fig 1 show the optical microstructure of Al-6Fe-1Si-1V alloy cast in 12mm diameter permanent mould, at a cooling rate of 20^0C/s.

The microstructure of cast Al-6Fe-1Si-1V alloy consist of platelet, star like, and irregular primary different phases of iron & silicon particles together with widely distributed eutectic silicon needles and few elongated α-Al dendrites. Chinese script type and interdendritic acicular phases were also present. The coarse platelet and star shaped particles acts as an internal stress risers in the microstructure and provides easy path for fracture and results decrease in mechanical properties (Basavakumar, 2007).

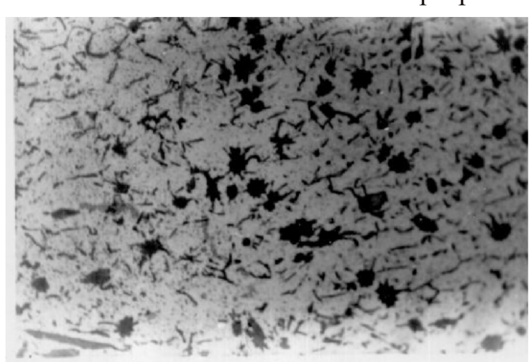

Figure 1: Optical microstructures of Al-6Fe-1V-1Si alloy, cooling rate 20^OC/s at 20X.

Scanning Electron Microscopy (SEM) Study

Scanning Electron Microscopy (SEM) has been carried out to confirm the nature of the precipitates of Al-6Fe-1V-1Si alloy which have been shown more clearly in Fig 2. The SEM photograph of alloy has thrown more light on the nature of the precipitates. Among the precipitates of different morphologies, the Chinese script and star shaped particles were observed in alloy Al-6Fe-1V-Si. It is clear from the photograph that star shaped precipitates are basically dendritic structures which decrease mechanical properties.

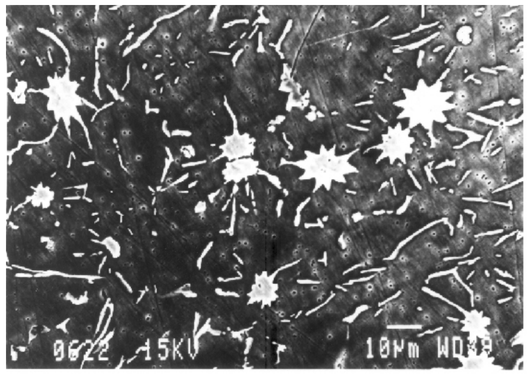

Figure 2: SEM micrograph of Al-6Fe-1V-1Si alloy, cooling rate 20^0C/s.

Mechanical Properties of Al-6Fe-1V-1Si Alloy

The mechanical properties of cast alloy have been discussed in this section, the properties of Al-6Fe-1V-1Si alloys were determined. The result of hardness, ultimate tensile strength (UTS), % elongation and % reduction in area (RA) as cast samples is given in the Table 1. Vickers hardness was measured under 5kg load. Average of three measurements of each as cast samples was taken. At the 6% Fe content, grains changes either in Chinese script or star shape structure which increases the stress raiser and consequently hardness increases. The massive iron bearing phases also adversely affect effective feeding in the casting (Sahoo *et al.*, 2000 & 2001) resulting in micro pores. Thus the mechanical properties deteriorate.

Table 1: Mechanical properties of as-cast samples.

Alloy	Hardness (VHN)	UTS (MPa)	% Elongation	% RA
A1-6Fe-1V-1Si	52	119	2.85	2

Conclusions

1. At 6% Fe content, grains appears either in Chinese script or star shape structure which increases the stress raiser and results deterioration in properties
2. Hardness of the alloy was determined as 52 VHN at 6% Fe content.
3. UTS increases to 119 MPa on the expenditure of percentage elongation which is only 2.85 at 6% Fe content.

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