Effect of Heat Treatment on Microstructure and Tensile Properties of A356/V$_2$O$_5$ Insitu Composites

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ABSTRACT
A 356 alloy reinforced with insitu V$_2$O$_5$ particles by using stir casting technique. The composites were produced by the addition of oxide particles in different weight percentage. The effect of oxide powder addition on microstructure and mechanical properties of produced composites were investigated. The effect of heat treatment on microstructure and mechanical properties were investigated by optical microscope, Microhardness tester and tension test. A significant improvement in hardness and tensile strength was revealed in the produced composite as compared to the base alloy. With the addition of oxide particles, the shape and size of eutectic Si changed which in turn affects the properties. It was observed that 2h solutionizing followed by the artificial aging was sufficient to make the structure homogenize and to produce the hardening precipitates. The improvement in the mechanical properties has been observed due to the age hardening precipitates in addition with refinement of insitu V$_2$O$_5$ particles.

KEYWORDS
A356 Alloy, Hardness, Heat Treatment, Microstructure, Tensile Property, V$_2$O$_5$

INTRODUCTION
Among the various aluminum alloys available, the Al-Si alloys have received the great attention due to their excellent properties (Torbian et al., 2010). Al-Si alloys are also known as the foundry alloys because of their good cast ability (Gruzleski and Closset, 1990). Aluminum-silicon alloys which are commercially available are divided in two groups hypoeutectic & hypereutectic. Both shows the wide range of applications due to their low density, low weight, good corrosion resistance & great cast ability. However, the main disadvantage is they are not heat treatable. The heat treatment capability of these alloys can be improved by the addition of magnesium. It was investigated in many studies that a Mg$_2$Si (secondary phase) will be formed within structure due to aging process. The formation of secondary phase is responsible for the precipitation hardening, which in turn improves the mechanical properties of these alloys (Zhu et al., 2010; Thirugnanam et al., 2007; Sharma et al., 2005). Therefore, Al-Si-Mg alloys have a wide range of applications in various fields specifically in automotive industry like cylinder head, cylinder blocks and many more cast engine components (Kumari et al., 2002).
The wear behavior of these alloys not only depends on mechanical properties like hardness, ductility, tensile strength but it also depends on the operating conditions like sliding velocity, load applied, environment and temperature, etc. (Clarke and Sarkar, 1979; Dwivedi et al., 2001; Chandrashekharajah and Kori, 2009). Previous studies reported that the mechanical properties governed by shape & size, rate of solidification, chemical composition, and grain refinement are responsible for wear behavior (Zhu et al., 2012; Wisely et al., 2007; Caceres et al., 1999).

Kori and Prabhudev (2011) reported that the refinement of α-Al dendrites takes place due to the addition of small percentage of Cu in A356, which in turns gives solid solution strengthening and found responsible for wear behaviour. The heat treatment efficiency of Al-Si hypoeutectic alloys influenced by holding time as well as the addition of alloying elements (Tokaji, 2005; Kliauga et al., 2008). Although the heat treatment is not easy in the case of Al-Si alloys but an attempt has been made by many researchers. Ji-Hua et al. (2011) reported that with short time treatment of A356 alloy properties like strength, elongation and maximum yield strength can be enhanced up to a great extent.

Mandal et al. (2009) has investigated the effect of TiB₂ addition in A356 alloy with insitu approach. The improvement in mechanical properties and wear behaviour has been reported. Another work related with microstructure and wear properties was reported (Pramod et al., 2015) with the 10% addition of TiB₂ in aluminum alloy. Around 2% Sc has also been added in the composite. The effect of addition reduced the SDAS (Secondary Dendrite Arms Spacing) and the changes in morphology of Si from needle like to fine spheroidal have been observed.

Zahid et al. (2011) revealed the Al₂O₃ phase formation due to the addition of CuO particles by insitu route. Effect of aging time and temperature on hardness has been reported in this research. Alemdeg and Beder (2014) stated that strength and hardness continuously increases with the addition of Zn content in Al-7Si alloy. The volume fraction and size of Si particles increases with the Zn addition. The paper also reported the decrement in wear volume with the Zn addition more than 4% by weight. So the reverse trend has been observed in case of Zn addition (more than 4%).

Standard heat treatment test for Al-7Si-Mg are made by many countries and they are well accepted. These tests include solution hardening and artificial aging. However, the main problems with these tests are they are time consuming and consume more energy like 4 hours for solution hardening & 6 hours for aging at 540°C and 150°C respectively.

In the present study A356 alloy is modified with vanadium pentoxide and the effect of heat treatment on microstructure and tensile properties were investigated. Short time heat treatment methods were used in this study.

**EXPERIMENTAL PROCEDURE**

Commercially available A 356 and extra pure AR grade V₂O₅ particles were used in this experiment. The chemical composition of as received alloy was determined by the optical emission spectrometer (SPECTROMAXx, AMETEK Germany) shown in Table 1.

A bottom pouring stir casting furnace (Swam Equipment, Chennai) was used for melting the aluminum alloy. The stirrer blade used in the experiment was made up of stainless steel having three bent and is coated with fine paste of graphite and dried so that no dissolution of steel in molten aluminum takes place.

A graphite mould of length 165mm and inner diameter 45mm was used for casting. The different amounts of V₂O₅ were weighed and added to molten alloy. Before the addition, particles were preheated

| **Table 1. Chemical composition of as received alloy (wt. %)** |
|---|---|---|---|---|---|---|---|---|---|
| Si  | Fe  | Cu  | Mg  | Mn  | Zn  | Ti  | Cr  | Ni  | Al  |
| 6.98 | 0.21 | 0.16 | 0.42 | 0.13 | 0.02 | 0.01 | 0.01 | 0.03 | Bal. |
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