CHARACTERIZATION OF ALUMINUM ALLOY PARTICULATE REINFORCED METAL MATRIX COMPOSITE

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ABSTRACT

Aluminum metal matrix composites are new engineering materials used in various fields of engineering. This paper highlights the synthesis of Al-Cu-Mg alloy – Titanium Dioxide particulates reinforced metal matrix composite used for the automotive application. The liquid metallurgy route, stir casting is used for the fabrication of metal matrix composite. The Titanium Dioxide was varied from 2 % to 6 wt % in steps of 2 wt %. The matrix material Aluminum alloy and the composite materials are subjected to artificial T-6 heat treatment. Hardness, tensile compression tests is conducted to characterize these materials. Optical microscopic observations of the microstructures revealed uniform distribution of particles in the matrix material. The result shows an improvement in hardness and tensile properties was observed with increasing weight percentage of titanium dioxide.

Key words: Aluminum alloy; Optical microscope; Heat treatment; Titanium Dioxide;

1. INTRODUCTION

The demand for the material having high stiffness, high strength, excellent wear resistance, outstanding dimensional stability, micro-creep resistance, micro-yield strength, high temperature capability, controlled coefficient of thermal expansion & the capability of operating effectively under adverse conditions led to the development of a new generation of materials know as composites. Metal matrix Composites have proved to be an important class of materials, with the potential to replace a number of conventional materials being used in automotive, aerospace, defense & leisure industries, where the demand for lightweight & higher strength is increasing [1].

The Aluminum matrix composites (AMC) refer to the class of lightweight high performance composites. Aluminum alloys are promising materials in high technology fields owing to their excellent specific mechanical properties. Aluminum alloy containing copper / Magnesium shows good response to heat treatment so that its properties can be optimized [2]. The Al –Cu-Mg alloy has been widely used as a cylinder head and piston material for the internal combustion engines. Alloy 2618 has stable elevated temperature strength compared to other 2XXX alloys. The hardening of this alloy is partly due to precipitation of Mg_2Si, $Al_4CuMg_5Si_4$ and other complex constituent second phase particles [3]. A major aircraft manufacturers are planning to produce a second-generation supersonic transport (Concord aircraft) to operate in the long-range international market. The alloy 2618 was selected for the primary structure of the Concorde, because of its static strength, fatigue strength and especially because of its creep strength. [4-5]. Most of the researcher investigated Aluminum matrix composites using Silicon carbide, alumina, zirconium and these composites are commercially available in a variety of Structural forms.

Use of TiO_2 as reinforcement in Aluminum alloys has received little attention although it posses high hardness and modulus with superior corrosion resistance. [6-9] In this light, an attempt is being made to develop Al –Cu-Mg alloy reinforced with TiO_2 particulates and to investigate its effect on the mechanical properties

2. EXPERIMENTAL PROCEDURE

2.1 Material used

The age hardenable Al –Cu-Mg alloy (Al 2618 alloy) was used as a matrix material and its composition is given in the table no1. Presence of Copper and Magnesium in the alloy shows good response to the heat treatment.

Table: 1 Composition of titanium dioxide

Cu	Mg	Ni	Fe	Si	Ti	Mn	Al
2.21	1.40	1.1	0.93	0.16	0.04	0.028	Bal

2.2 Reinforcement

Titanium Dioxide (TiO2) of laboratory grade material was used as reinforcement. Titanium Dioxide is a ceramic material having high hardness and low coefficient of thermal expansion. It has got a high wear resistance and thermal shock resistance. [7]

2.3 Composite preparations

Liquid metallurgy route, stir casting is used for the production of Aluminum metal matrix composites [10]. Two kilograms of Al –Cu-Mg alloy billets were cut into pieces to accommodate into the Graphite crucible. The temperature of the furnace was slowly raised above the liquideous temperature of the melts and then slowly reduced below liquideous temperature of the matrix material. At this stage, the preheated, calculated quantity of TiO_2 particulates were slowly added into the semi-liquid melt. After sufficient manual mixing, the temperature was slowly raised above liquideous temperature. At this stage, stirring was carried out for about 10 minute duration at a stirring speed of 300 rpm. The slurry was poured into preheated C.I. Moulds of different sizes and shapes. The Titanium Dioxide was varied from 0 % to 6 wt % in steps of 2 wt % and three types of composites and the base material were prepared.

2.4 Heat treatment

The composite specimens were subjected to T6 heat treatment standard. First the specimens were solutionized at 529^0C for 2 hrs in a muffle furnace of accuracy $\pm$ 1^0C and then water & ice quenched. The quenched samples were aged at 199 ^{o} C for 8Hrs time duration.

3. TESTING

3.1 Hardness test

A Brinell hardness tester was used which has a ball indentor diameter of 10mm, a minor load of 250 Kgs and a major load of 250 Kgs. The load was applied for 30 seconds to obtain an indentation, which would be representative of the macrostructure of the material. Three hardness reading was taken for each specimen at three different locations to circumvent the possible effects of particle segregation.

3.2 Tensile and compression testing

The tensile tests were carried out on a computerized universal testing machine. A strain rate of 0.51 mm/min was adopted. The specimen dimensions were as per ASTM E8-04 standards and is shown in figure 1. The tensile testing was performed on computerized uniaxial tensile testing machine at room temperature. The specimens were loaded at the rate of 0.51mm / min. Each experiment was repeated twice and the average response value was considered. The compression test was conducted on a specimen of diameter 13mm and length 25 mm. The compression load was applied gradually and corresponding strain was measured by the failure of the specimen occurred.

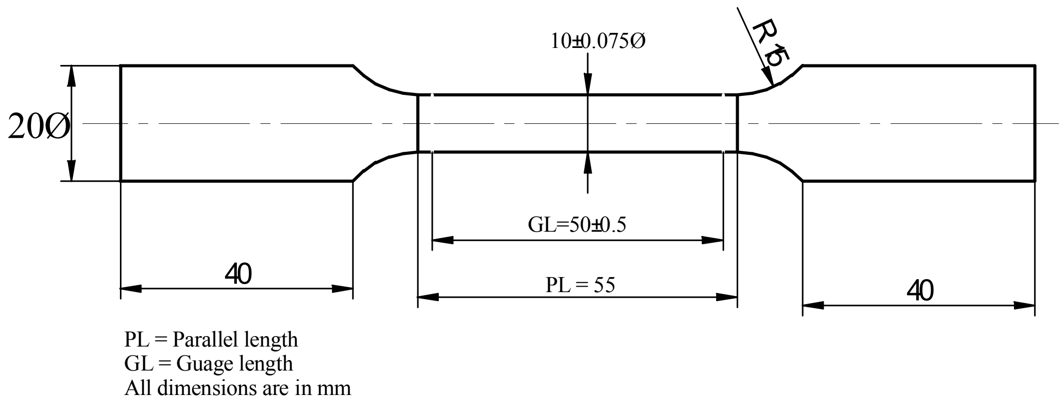

Figure 1 Tensile test specimen

4. RESULTS AND DISCUSSION

4.1 Optical micrograph studies

Figure 2 shows the microstructure of as cast Al –Cu-Mg alloy t. In the as received samples, precipitations were evident both in the grains and along grain boundaries.

Figure 3 depicts the microstructure of Al –Cu-Mg alloy reinforced with 6 % TiO_2 after T6 heat treatment. Micrographs clearly reveal minimal microporosities in the casting. It can be seen that the TiO2 particles are well distributed in the composite and no clustering of particulates can be seen in the composite material. It is evident from the micrograph that, fine coarsening occurs after samples were heat-treated [3]. This enhances the properties of the composites.

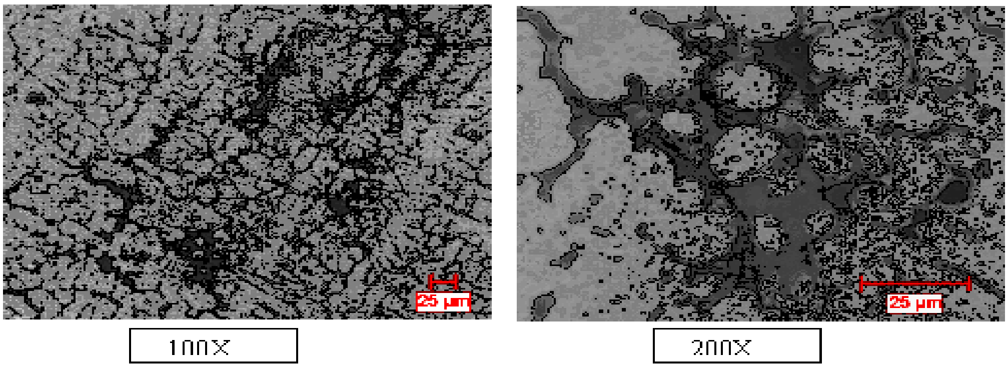

Figure 2 Optical microscopy cross – sectional view of Al 2618 alloy

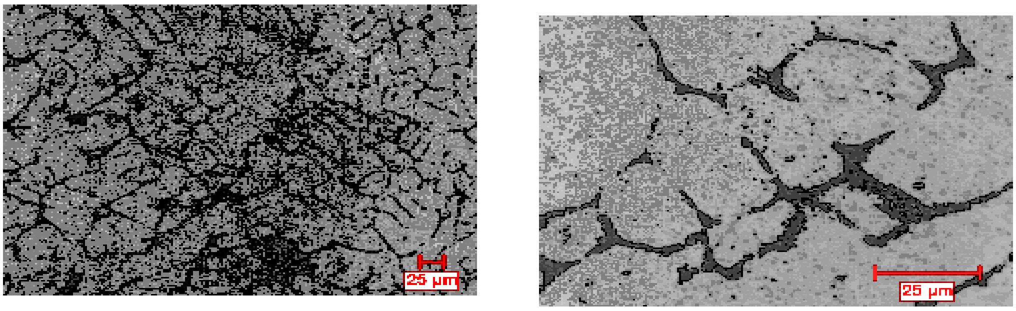

Figure 3 Optical microscopy cross – sectional view of T6 heat-treated Composite containing 6-weight % of TiO_2

4.2 Brinell hardness

Fig. 4 shows the Brinell hardness values Al –Cu-Mg alloy and the composite containing different weight percentage of titanium dioxide. The figure shows that the addition of Titanium dioxide into Al –Cu-Mg alloy enhanced the hardness of the composite. An increase in the hardness of the composite is because of hard Titanium dioxide particulates dispersed in the soft Aluminum matrix material. [8]

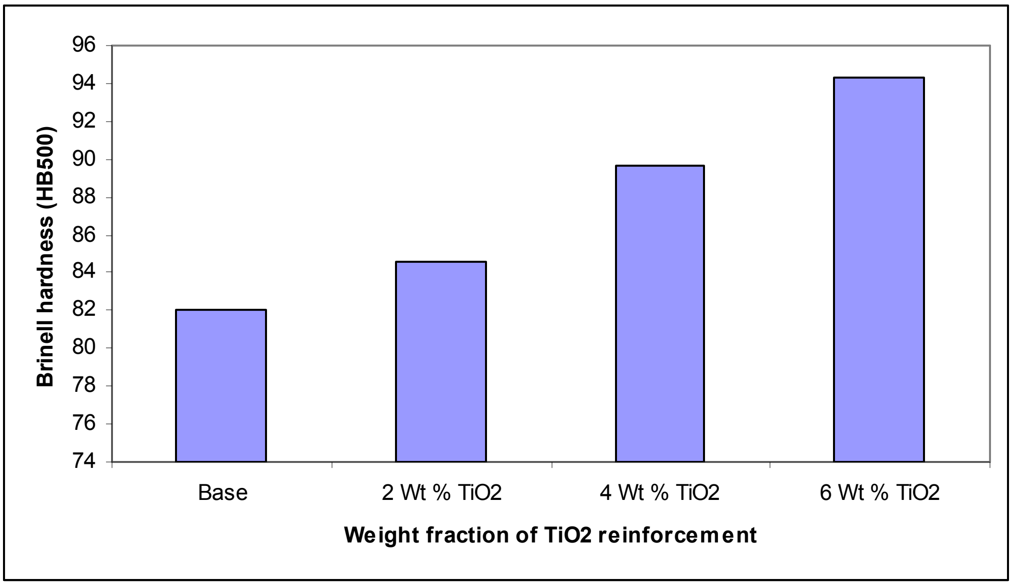

Figure 4 Hardness of Base materials and TiO_2 composite

4.3 Tensile strength

Figure 5 shows the increase in the ultimate tensile strength of the composites as the weight percentage of Titanium dioxide increased. Wettability is one of the dominating factors to ensure good bond between the matrix and the reinforcement. [11] The magnesium added during the composite synthesis acts as a gas scavenger from the dispersoid surface, thus thinning the gas layer and improving wetting and reaction –aided wetting with the surface of the dispersoid. The combination of magnesium and aluminum seem to have a synergistic effect of wetting. A good bond between the matrix and reinforcement always favors an improvement in the ultimate tensile strength of the composite. [12]

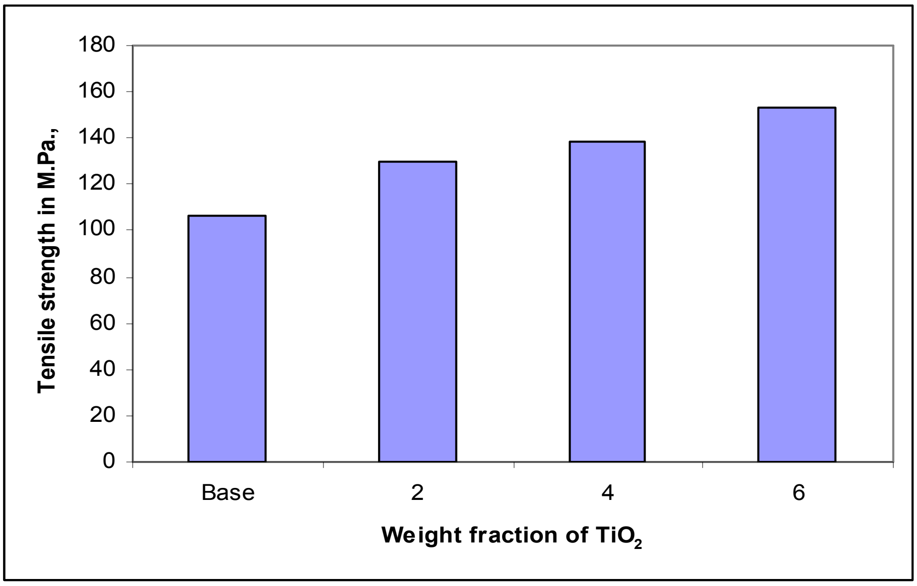

Figure 5 : Tensile strength of Base material and TiO_2 composite

4.4 Compression strength

Figure 6 depicts the compression behavior of the composite as the weight percentage of titanium dioxide. This increase in the compression strength is because of the presence of hard particles, which imparts high strength to the composites. [13] This may be due to very small amounts of particulates at different orientations, which can make tremendous difference in stress – strain behavior. The rigidity and crushing strength of particles is much higher than that of matrix material hence the strength increases. [8, 9, 14]

Figure 6: Compressive strength of Base material and TiO2 composite

5. CONCLUSIONS

The following conclusions have been drawn from the above study

- Aluminum matrix composites have been successfully fabricated with fairly. Uniform distribution of Titanium dioxide particles.
- An increase in the hardness of the composite is because of hard Titanium dioxide particles dispersed in the soft Aluminum matrix material.
- The Tensile strength and compressive strength were affected by the addition of titanium dioxide particles in the matrix material. A good bond between the matrix material and reinforcement always favors an improvement in the strength of the composite.

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