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This paper discusses the mechanical properties of Titanium Carbide (TiC) particulate reinforced aluminium-silicon alloy matrix composite. TiC particulate reinforced LM6 alloy matrix composites were fabricated by carbon dioxide sand molding process with different particulate weight fraction. Tensile strength, hardness and microstructure studies were conducted to determine the maximum load, tensile strength, modulus of elasticity and fracture surface analysis have been performed to characterize the morphological aspects of the test samples after tensile testing. Hardness values are measured for the TiC reinforced LM6 alloy composites and it has been found that it gradually increases with increased addition of the reinforcement phase. The tensile strength of the composites increased with the increase percentage of TiC particulate.

Keywords: composite materials, aluminium alloys, crystal microstructure, tensile strength; Dispersion-, fiber-, and platelet-reinforced metal-based composites, Metals, semimetals, and alloys, Cold working, work hardening; annealing, post-deformation annealing, quenching, tempering recovery, and crystallization, Deformation, plasticity, and creep
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Abstract. This paper discusses the mechanical properties of Titanium Carbide (TiC) particulate reinforced aluminium-silicon alloy matrix composite. TiC particulate reinforced LM6 alloy matrix composites were fabricated by carbon dioxide sand molding process with different particulate weight fraction. Tensile strength, hardness and microstructure studies were conducted to determine the maximum load, tensile strength, modulus of elasticity and fracture surface analysis have been performed to characterize the morphological aspects of the test samples after tensile testing. Hardness values are measured for the TiC reinforced LM6 alloy composites and it has been found that it gradually increases with increased addition of the reinforcement phase. The tensile strength of the composites increased with the increase percentage of TiC particulate.

Keywords: tensile, fracture surface, LM6 alloy, TiC particulate.
PACS: 60

INTRODUCTION

Industrial technology is growing at a very rapid rate and consequently there is an increasing demand and need for new materials. Particulate reinforced composites constitute a large portion of these new advanced materials. The world of tomorrow will probably involve a synergistic mix of materials rather than the replacement of one material by another. In pursuit of this, the last few decades have witnessed unprecedented developments of harder metals and alloys. One example is composite materials, the metal matrix composites (MMCs) which are increasingly being used in the automobile, aircraft, and space industries. As a result, worldwide attention has been focused on the processing and fabrication of these materials because of both manufacturing costs and performance. These composite materials also offer outstanding properties such as high strength-to-weight ratio, high torsional stiffness, good corrosion resistance and good tolerance characteristics and versatility to the designer [1]. The choice of the processing method depends on the property requirements, cost factor consideration and future applications prospects. The advantage of processing composites by casting technology leads to near-net shape manufacturing which is a simple and cost-effective process [2]. Incorporation of hard second phase particles in the alloy matrices to produce MMCs has also been reported to be more beneficial and economical [2,3,7] due to its high specific strength and

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corrosion resistance properties. SiC, TiC, TaC, WC, B4C are the most commonly used particulates to reinforce in the metal or in the alloy matrix or in the matrices like aluminium or iron. However, very limited studies of silicon dioxide reinforcement in LM6 alloy have been reported and so the information and the data available on the mechanical properties and fracture surface analysis are scarce and hence make this study a significant one. In this investigation, quartz particulate reinforced LM6 alloy matrix composites test samples fabricated and processed by casting method are chosen [4,5]. The parameter of different percentage of TiC particulate addition in the LM6 alloy matrix is examined to study the mechanical behavior and fracture surface characteristic used tensile testing of the processed specimens. Tensile test, hardness testing and Scanning Electron Microscopy are employed to evaluate the maximum load, tensile strength and to characteristic the morphological features of the fracture surfaces in titanium carbide (TiC) - particulate reinforced LM6 alloy composites after the tensile testing.

METHODOLOGY

Materials Preparation

The materials used in this work were Aluminium LM6 alloy as the matrix and TiC as reinforcement particulates with different percentages. The tensile test specimens were prepared according to ASTM standards B 557 M-94 [6]. Sodium silicate and CO_2 gas is used to produce CO_2 sand mould for processing composite casting. The aluminium alloy, LM6, was based on British standards that conform to BS 1490-1988 LM6. Alloy of LM6 is actually a eutectic alloy having the lowest melting point that can be seen from the Al-Si phase diagram. The main composition of LM6 is about 85.95% of aluminium and 11% to 13% of silicon. The details of the LM6 alloy composition is shown in Table-1.

TABLE 1. Composition of LM6 (%)

Al	Cu	Fe	Mg	Mn	Ni	Pb	Si	Sn	Ti	Zn
85.95-87.95	0.1	0.6	0.1	0.5	0.1	0.1	10-13	0.05	0.2	0.1

Fabrication of composites

Carbon dioxide moulding process was used to prepare the specimens as per the standard moulding procedure. Titanium carbide reinforced MMCs were fabricated by casting technique. Four different weight fractions of TiC particle in the range from 0.2, 0.6, 1 and 2 %wt are used. An induction furnace was used to melt the aluminium alloy and TiC was mixed in it after the alloys attains the liquid state. The main concern was to maintain the temperature while transferring the molten metal to the mould and hence to ensure the quality of the cast product. The metal handling equipment used to transfer the molten metal also depends on the mould size and quality of cast being cast. Figure 1 shows the LM6 ingots, processing of the composite and pouring into mold.

a. LM6 ingots b. Casting process c. Pouring Process

FIGURE 1. Processing of the composite specimen

Tensile testing

Tensile test was conducted to determine the mechanical properties of the processed TiC particulate reinforced LM6 alloy composites. Test specimens were made according to ASTM standard B557 M-94. The test samples were subjected to a tensile load and the mechanical properties were determined. Hence, the tensile strength values were calculated. A thin flat material with a constant rectangular cross-section was mounted and gripped in the INSTRON 8500 UTM testing machine and it was monotonically loaded in tension while recording the load. The test coupon strain was monitored for accuracy with displacement transducers where the stress-strain response of the material can be determined and hence the modulus of elasticity can be calculated. Figure 2 shows the specimens before and after testing.

a. Specimen before testing b. Spesimen after testing

FIGURE 2. Tensile Speciment of composite

Scanning electron microscopy

Scanning Electron Microscope (SEM) using Hitachi S-3400N variable pressure microscope with Inca 300 Energy Dispersive X-ray (EDX) and model 8500 INSTRON UTM testing machines are used to test the tensile specimens of TiC particulate reinforced LM6 alloy matrix composites and its fracture surfaces are analyzed after tensile testing. Results and data obtained from the tensile tested samples are correlated with the reported mechanical properties for each weight fraction of TiC percentage addition to the LM6 alloy matrix.

Hardness measurement

The hardness of the composites were tested by using MITUTOYO ATK-600 MODEL hardness testing machine. For each sample, then hardness readings were taken randomly from surface of the samples. Hardness values of different types of the processed composites are determined for different weight fraction % of titanium carbide particulate containing aluminium-11.8% silicon alloy and graphs are plotted between the hardness value and the corresponding type of particulate addition on weight fraction basis.

RESULT AND DISCUSSION

Tensile testing

The tensile testing of the samples was performed based on the following specifications and procedures according to the ASTM standards.The Table 2, shows the effect of TiC on tensile strength and hardness test of the composite. The tensile properties of the LM6/TiC MMC for four different weight fractions at ambient temperature reveals an increases in tensile strength and hardness with increase in reinforcement content in the LM6 alloy matrix. The graph plotted between the average tensile strength and hardness values variation in percentage weight of TiC particulate addition to LM6 alloy indicated that both the properties increases with increase of TiC particulate. The increases of tensile strength and hardness of the TiC particulate reinforced LM6 alloy composite with increased addition in weight fraction of TiC particulate is explained as follow with reference to the Figure 3a. The increase in tensile strength may be due to the TiC particles acting as barriers to dislocations in the microstructure. This dislocation increases the dislocation density, which provides a positive contribution to strength of the composite. This result was well supported and evidenced from the literature citation. [8,9]

Table 2. Tensile properties of MMC containing various amounts reiforcement content.

wt% of TiC	**Tensile Strength (MPa)**	**Hardness based on Rockwell superficial 15T**
0	116.0743	79.91
0.2	123.9025	81.06
0.6	130.9343	81.32
1	133.9486	83.90
2	135.8325	85.88

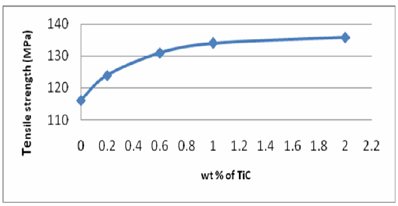
The examine fracture surface of an LM6 matrix composite surfaces exhibit a brittle cleavage fracture mechanism. The fracture surface of the grain refined composite showed broken Aluminium and TiC particles (Figure 4a to 4e) and well-attached particles within the dimples, indicating rather good interface cohesion between matrix and reinforcing particles.

Hardness measurement

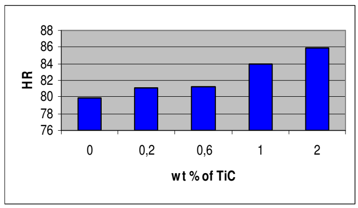
Data on the hardness of combined particulate reinforced composites made in sand mold is analyzed. It is found that the hardness value increases gradually with the increased addition % by weight and it is shown below in the graph as Figure 3b. The maximum hardness value based Rockwell superficial 15N-S scale is 85.88 for 2% weight fraction addition. Based on the above figure, variation in hardness value of the composites corresponding to the variation in weight fraction of titanium carbide particulate can be known. It is clear in this figure that the hardness value of the processed composites increases with the increase in addition of titanium carbide particulate by weight fraction %.

Fractography

Fracture surface investigation of composite samples is performed by using HITACHI S-3400N variable pressure microscope with Inca 300 Energy Dispersive X-ray (EDX). By using it, fracture surfaces of the tensile tested samples are observed at higher magnifications to characterize the type of failure. Then, studies on the interphase and bonding are performed to observe the formation of interfacial reaction products and to predict the type of bonding between the particulate surface and the matrix surface. The examined fracture surface of an LM6 matrix composite surfaces exhibit a brittle cleavage fracture mechanism. The fracture surface of the grain refined composite showed broken Aluminium and TiC particles (Figure 4a to Figure 4e) and well-attached particles within the dimples, indicating rather good interface cohesion between matrix and reinforcing particles.

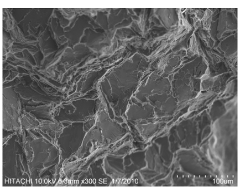


a. Average tensile test versus weight fraction of TiC

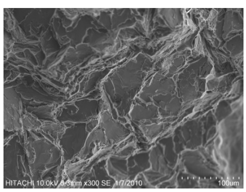


b. Average hardness l versus weight fraction of TiC

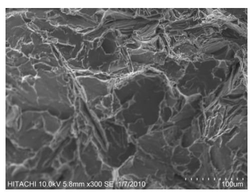
FIGURE 3. Average tensile strength and *hardness Rockwell* versus weight fraction of TiC



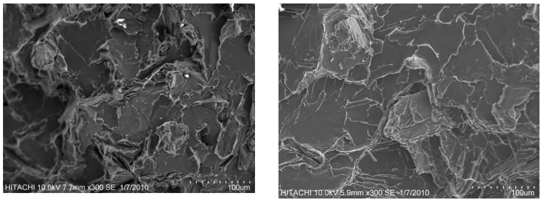
a. Fractograph of LM6 at 300X magnification



b. Fractograph of 0.2% TiC at 300X magnification



c. Fractograph of 0.6% TiC at 300X magnification



d. Fractograph of 1% TiC at 300X magnification

e. Fractograph of 2% TiC at 300X magnification

FIGURE 4. SEM micrographs of fracture surfaces of the TiC particulate reinforced LM6 alloy matrix composite

CONCLUSION

Based on the experimental evidence from this research work the following conclusions are drawn:

1. The split tensile strength values increased gradually as the titanium carbide content in the composite increased by weight fraction. The reason for this mechanical behavior is due to the dominating nature of the compressive strength of the Titanium carbide particulate reinforced in the LM6 alloy matrix.
2. The hardness value of the titanium carbide reinforced LM6 alloy matrix composites is increased with the increased addition of titanium carbide particulate in the matrix.
3. The mechanical behavior of the processed composite had a strong dependence on the weight fraction addition of the second phase reinforcement particulate on the alloy matrix

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