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Investigations on the Mechanical Properties of AA6063-TiC Metal Matrix Composites with and without heat treatment

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Abstract: The mechanical properties of AA60633-TiC Metal matrix composite, which is prepared via a liquid metallurgical technique and consists of Aluminum alloy 6063 with different percentages of 2%, 4%, and 6% titanium carbide, have been the focus of this investigation. The investigations on mechanical strength and hardness are carried out with heat treatment. When compared to the findings of the research carried out on material samples that did not undergo heat treatment, the results reveal that heat treatment resulted in improved mechanical strength and hardness.

***Index Terms*–AA6063 (Aluminium Alloy6063), TiC (Titanium Carbide), Heat treatment.**

I. Introduction

The increasing demand for high-performance scientific and technical domains has led to the widespread implementation of aluminum metal matrix composites in industries like aerospace, structural, automotive, and sports. When it comes to reinforcing materials, the combination of materials and procedures used to make them has a significant impact on their performance. Aluminum's outstanding mechanical and tribological qualities, combined with its low density and high strength-to-weight ratio, make it a widely used metal. [1-2]

AA6063 – Matrix material: In addition to aluminum, AA6063 also includes magnesium and silicon. The AA6063 aluminum alloy is often considered the best choice for extrusion. Complex shapes can be made with very smooth surfaces that are anodization-friendly, making it a popular material for structural applications in the aerospace and automotive industries.

TiC – Reinforcement: Titanium carbide (TiC) is a refractory ceramic with a high hardness; crystals of this substance found in nature are typically between 0.1 and 0.3 mm in size, making it an excellent reinforcement material.[3-5]

Fig 1: Aluminium Alloy 6063

Fig 2: Titanium Carbide of mesh size 100 -300

Fig.1 shows the casted aluminum alloy 6063, which is composed of the following elements: Si (0.02%), Mg (0.8%), Fe (0.02%), Cu (0.02%), Zn (0.02%), and Cr (0.02%).

Fig. 2, Represents the Titanium Carbide of mesh size 100-300 ASTM standards.

Table 1: Properties of TiC

Density	Melting Point	Hardness Vickers(VH)	Elastic Modulus	Shear Modulus
4.93 g/cm^3	3160°C	2850 VH	440 GPa	188 GPa

II. FABRICATION TECHNIQUE:

A metal matrix composite can be fabricated using a variety of techniques, including the liquid metallurgy process, Stir casting, powder metallurgy, squeeze casting, and die casting. Stir casting is the best and cheapest method for producing metal matrix composites. In this work, Al 6063-TiC MMCs are created using a stir-casting method. In MMCs, TiC was present at 2%, 4%, 6%, and 8% varying from one to the next. Cylindrical rods are used to cast test specimens in accordance with ASTM standards, and the muffle furnace and dies used in this procedure are depicted in Figure 3. General casting characteristics for aluminum alloys are listed in Table 2. [6-8]

Fig 3.a & 3.b: Muffle furnace used for heating aluminum alloy Fig 3.c: Dies

Table 2: Casting parameters

Stir Casting	Temperature	750ºC to 850°C
	Stirring Speed	150 to 500 pm
	Stirrer blades	4 blades at 35° Position
	Muffle Furnace	0 to 1000°C
	Metal Die	Hardened Steel

2.1 Optimization of stirring parameters

Achieving particle uniformity using the liquid metallurgical technique is exceedingly challenging due to the high density of reinforcements. Optimization of stirring parameters and their effect on the properties of Al 6063 TiC MMCs are examined. The experimentally optimized parameters for the aluminum alloy are shown in table 3 below. [9]

Table 3: The optimized values of the stir casting

Stirring parameters	Range of values	Optimized value
Stirring Temperature	750ºC - 850ºC	800ºC
Stirring Time	2 - 5 minutes	3 minutes
Stirring Speed	150 – 500 rpm	350 rpm

2.2 Density measurements

Al 6063 has a density of 2.69 g/cc, while TiC has a density of 4.93 g/cc. The density of MMCs was calculated using the Archimedes method, and the theoretical density of Al 6063 TiC MMCs was obtained using the law of mixtures. Increasing the reinforcing percentage led to a greater composite density. By increasing the density of the reinforcement, the mechanical and tribological properties of the composite are improved.[10]

2.3 Optical Studies &XRD studies

Microscopical and electron microscopical examinations of Al 6063 TiC MMCs confirm the material's asserted even distribution of TiC throughout the matrix. X-ray diffraction testing confirmed that Al 6063 alloy contains TiC. X-ray diffraction research confirmed the existence of TiC in Al 6063 alloy. Figure 4 demonstrates how the microstructural characteristics of Al 60663 TIC changed across the range of reinforcement percentages used in the tests. Etched specimens for electron microscope microstructure examination are shown in Figures 5 and 6.

Fig 4: Preparation of test samples for microstructural features of Al 60663 TIC.

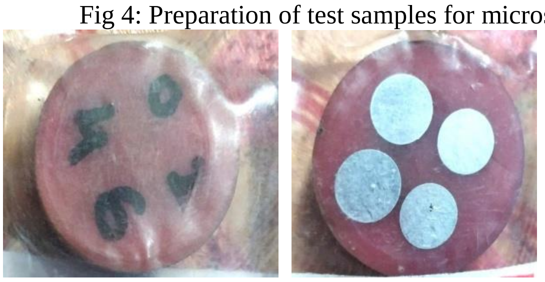


Fig 5: Etched samples for microstructural analysis of 0%, 2%, 4%, 6% TiC with AA6063

Fig 6: optical microscope

2.4 Hardness Studies

The microhardness of a composite material is a good indicator of the bonding strength between the reinforcing particles and the matrix. The diamond indenter was used to apply a weight of 100 g for 10 seconds during the hardness test. This method was carried out in accordance with the requirements set forth by the American Society for Testing and Materials (ASTM) in their document E92. The hardness specimen samples are depicted in Figure 4.

2.5 Tensile Studies

A computerized universal tester is used to examine the tensile behavior, yield strength, and elongation % of Al 6063 TiC MMCs. The specimens are prepared in accordance with ASTM E-8 standards. The specimen was 31mm in length and 10mm in width. Figures 7 and 8 show the ASTM-8 tensile specimen size and the correspondingly constructed specimens.

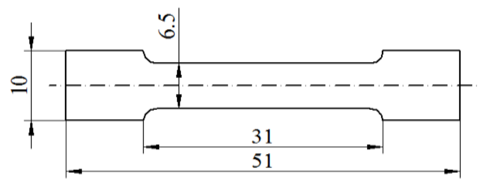


Fig 7: Shows the Tensile specimen size ASTM-8

Fig 8: Prepared test samples as per ASTM-8

III. RESULTS&DISCUSSION

3.1 Optical studies

Figures 10, 11, and 12 display the visibility of the TiC particle reinforcement in the Al 6063 matrix after optimizing the fabrication conditions.

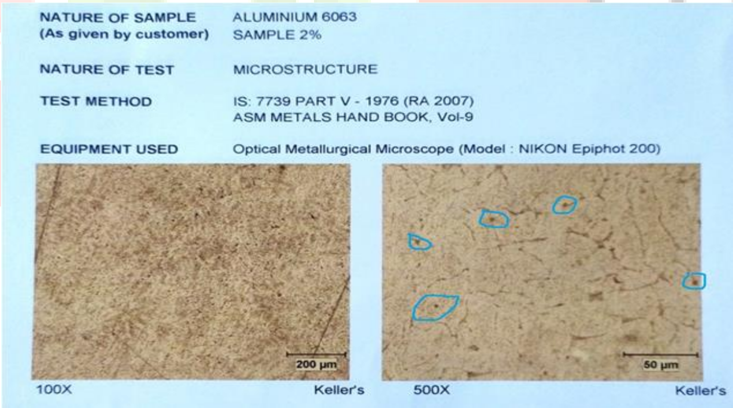


Fig 10: Optical microscope image of 2% TiC with AA6063

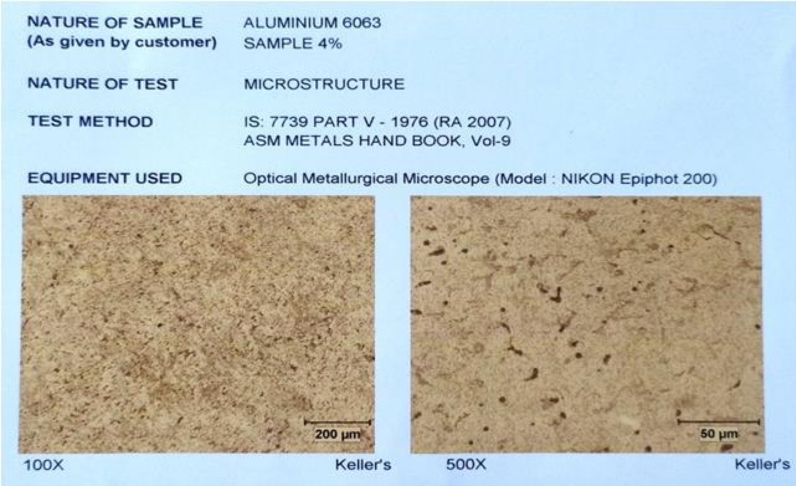


Fig 11: Optical microscope image of 4% TiC with AA6063

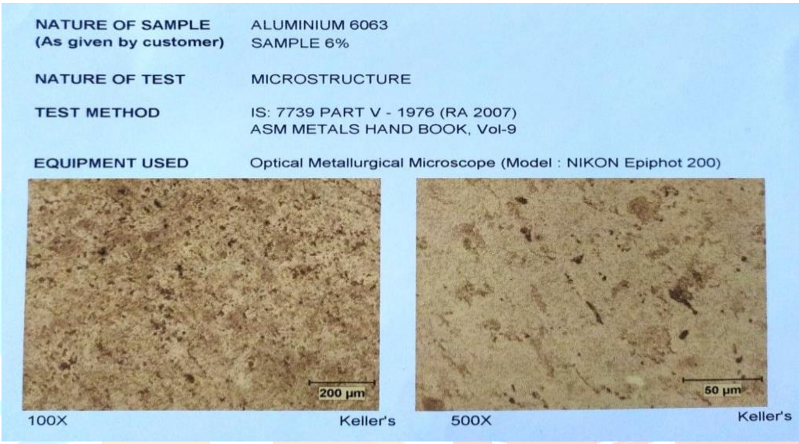


Fig 12: Optical microscope image of 6% TiC with AA6063

Fig 15: XRD Studies Al 6063 – 6 %TiC

3.2 Density Calculations – Theoretical density

Theoretical density of Al 6063 - TiC MMCs fabricated by liquid was determined by knowing the weight fraction of each constituent.

$$\frac{100}{\rho_{th}} = \frac{\text{TiC wt.\%}}{\rho_{TiC}} + \frac{\text{Al wt.\%}}{\rho_{Al}}$$

where,
ρ_{th} = Theoretical density
ρ_{TiC} = Density of TiC
ρ_{Al} = Density of Aluminum

3.3 Density Calculations – Experimental density

The balancing lever method was utilized in order to obtain an accurate reading of the MMCs' relative density. Due to the fact that the density of water is 1 gram per cubic centimeter, the experimental density of MMCs will be equivalent to the relative densitythat is measured.

$$\text{Relative density} = \frac{\text{Weight of Al 6063−TiC MMCs in air}}{\text{Loss of weight in water}} \qquad \text{Porosity} = \frac{\rho_{th} - \rho_{exp}}{\rho_{th}}$$

3.4Hardness Results

Results from a Brinell hardness tester are tabulated for the test specimen and displayed in figure 16 below.

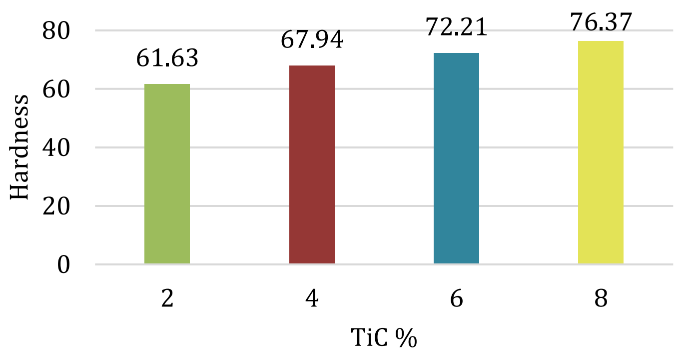
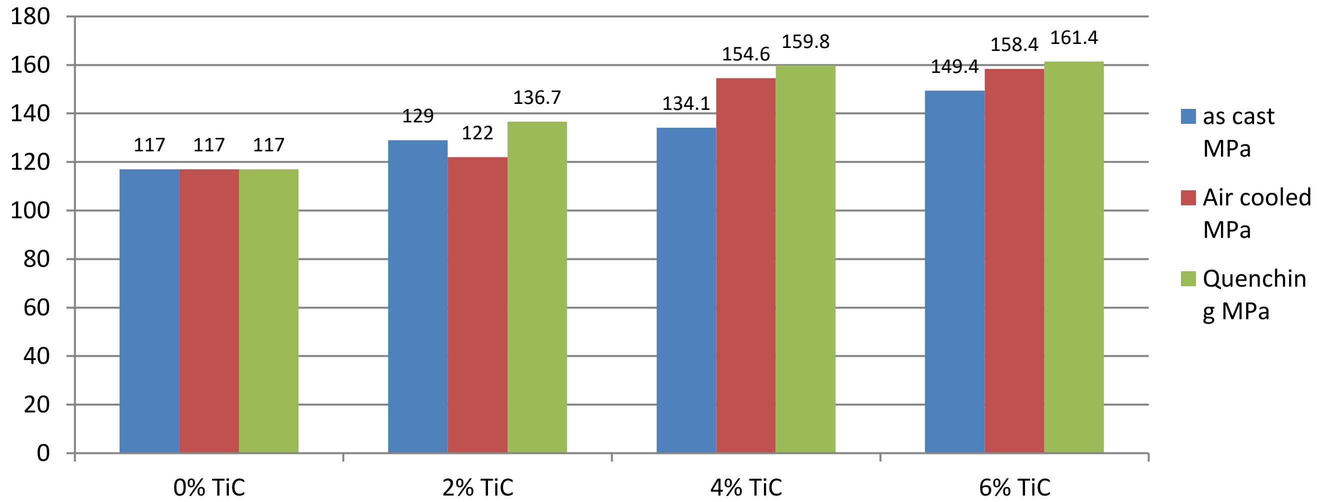


Fig 16: Graph of Brinell hardness number [BHN] of the test specimen.

3.5 Tensile Studies: Al6063 – TiC MMC

The results of tensile tests carried out on various composites mixtures with air-cool, and T6 heat-treated conditions, and an oil quenching procedure are presented in figure 17 down below.

	As cast MPa	Air-cooled MPa	Quenching MPa
0% TiC	117	117	117
2% TiC	129	122	136.7
4% TiC	134.1	154.6	159.8
6% TiC	149.4	158.4	161.4



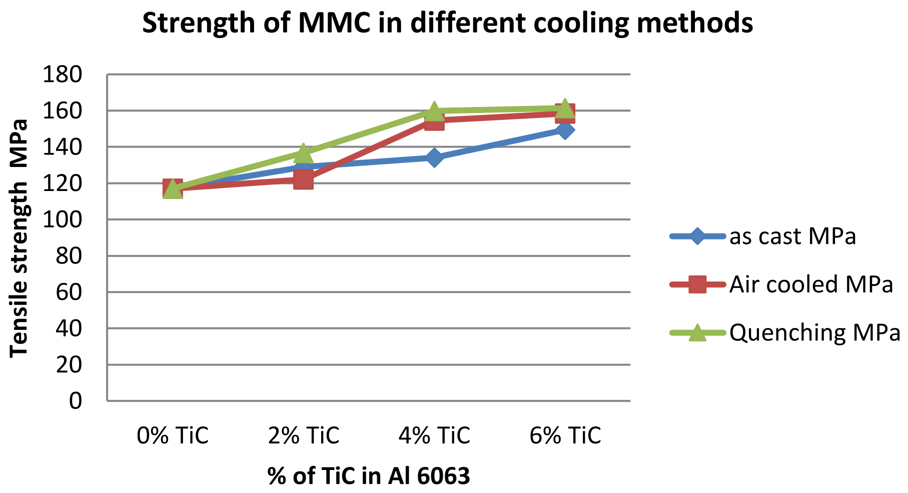


Fig17: Graph of tensile strength of Al 6063 with 0,2,4,6 % of TiC.

The above results show that the tensile strength of the heat-treated specimens is hardened at heat treatment, and the specimen strength increased with varying percentages of TiC.

4. CONCLUSIONS

By changing the TiC content from 2% to 4% to 6%, we were able to effectively produce Al6063-based TiC-reinforced MMC utilizing a liquid metallurgical technique. Composites' hardness and tensile strength, for example, are among the mechanical qualities investigated. The results of this research suggest the following.

In order to create the composite material, the proportion of TIC reinforcement is changed, and the process parameters are then tuned. An electron microscope, seen at 500X magnification, confirmed the structure's integrity by showing that particles were evenly dispersed throughout the material.

According to the results of the hardness test, the proportion of TIC has a positive effect on hardness.

When subjected to a tensile test in a tensometer in accordance with ASTM standards, it was discovered that oil quenched T6 heat-treated specimens have a higher tensile strength than casted specimens. In this case, heat treatment is used to harden the specimen.

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