

The Effect of TiC on Microstructure and Mechanical Properties of AA 2024 MMCs

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Abstract. The present work describes the mechanical properties of AA 2024 metal matrix composites reinforced with TiC. TiC particles of size 325 mesh were taken as the reinforcement material to prepare the metal matrix composites by using stir casting technique. The percentage of reinforcement varied from 0 to 6% wt in steps of 2%. Mechanical characterization such as tensile strength, hardness test, density tests were conducted as per ASTM standards. Experiment results reveal that there is an improvement in Ultimate tensile strength and hardness properties with the increase in the weight percentage of reinforcement. Optical microscopy technique was used to examine microstructures of the sample specimens and the microstructure revealed uniform distribution of particles and presence of reinforcements in the matrix phase. Experimental studies invoke that the 6%wt of TiC increases the tensile strength by 8% and hardness values by 9% comparing with that of as cast AA2024. Results also evident that there was a decrease in ductility and percentage of elongation with the increase in the percentage reinforcement.

1. Introduction

Bauxite ore is a chief source of aluminum alloy. Aluminum 2024 is a light weight material hence used for automotive applications and aircraft material. Main alloying element of AA2024 is copper and its main advantageous engineering properties are high strength to weight ratio, moderate machinability, and resistance to fatigue. Boron carbide is a ceramic material of typically brittle in nature and its crystal structure is of complex nature of icosahedron-based borides. Main properties of Titanium carbides are Low thermal conductivity, Susceptible to thermal shock failure, outstanding hardness, extremely brittle, Semiconductor, Good thermal-neutron capture. In the present investigation AA2024 is used as matrix phase and Boron carbide is used as a reinforcement material for strengthening of the MMC's.

Al 2024 Alloy reinforced with B₄C particles (2µm), processed by stir casting have been studied. Al 2024 matrix with 9% of B₄C particulates shows higher micro-hardness. Further it shows more resistance to wear with the increase in B₄C particles. However, with the increase of B₄C beyond 9% does not show any considerable improvement in resistance to wear. Experimental results show that by



increasing percentage of reinforcement it founds that increasing wear rate and wear volume. Aluminum alloy 356 reinforced with B₄C produced by two step stir casting method with different weight % [1].

Results shows decrease in wear rate with the higher hardness number. Results indicated that tensile properties increased with increase in % of B₄C. Optical microscopy study reveals that uniform dispersion of reinforcement [2].

Mohan et.al investigated the Mechanical and tribological properties of hybrid composites, were AA430 was used as a matrix material, SiC and MgO was used as reinforcement material using Liquid metallurgical technique. Experimental results showed that increasing the percentage of reinforcement increases the tensile strength and also the hardness. It further showed increasing the percentage of SiC+MgO, the coefficient of friction is decreases. Al6061 alloy reinforced with the TiC is fabricated by using stir casting technique [3]. Aluminum alloy reinforced with ceramic particle like TiC is significantly used in automobile, aircraft, marine, sports and recreation application.

Mohan Kumar and Govindaraju investigated on fracture behavior of Aluminum 7075 alloy with an Electroless Nickel coating with different thickness. SEM revealed that the adhesion between the 7075 alloy and Nickel coating was strong and the coating was uniform. Fracture toughness of the coated specimen increased significantly with coating thickness [4]. Aluminum 7075 alloy with different thickness of zinc / cadmium coating also increases Fracture toughness value in compared to that of uncoated aluminum 7075-T6 alloy [5].

Pramod R and Shashi Kumar M.E. evaluated the mechanical and insulation properties of Nomex-T410 and HS glass polymer matrix composites. This had enhanced the mechanical properties and at the same time contributing to the superior electrical insulation properties through dielectric test when compared to the existing insulators. The PMC also proved its chemical inertness and sustained higher temperatures [7].

Dhinakaran et.al investigated the mechanical properties of A6061-B₄C MMC with varying percentage of reinforcement. According to the ASTM standards tensile, hardness properties were evaluated. AA6061-B₄C reinforced MMC exhibited a very good mechanical properties under the T6 heat treatment condition compared to the as cast MMC of Al6061 alloy and also dry sliding behaviour of AA6061-B₄C under T6 exhibits a very good wear resistance with the increased wt. % of reinforcement [1].

2. Methodology

2.1 Liquid Metallurgy Technique

Aluminum 2024 alloy series were used as the base alloy and Boron carbide as reinforcement material. The reinforcement particle size used was 325 µm and was preheated to 500°C. To increase the wettability of molten metal magnesium chips were added, as the molten metal starts to solidify at a faster rate. Adding more than 5% would lead to porosity of the base metal. Molten Aluminum was stirred with reinforcements at a constant speed of 350 rpm for 10 min so that it creates a vortex and enhances the uniform distribution throughout the matrix phase which is necessary for adjoining the reinforcements with matrix material. The Figure.1 shows the molten metal in the furnace crucible and Figure.2. Shows the stirring of AA2024 with TiC reinforcement. Figure.3 shows the pouring of molten metal in to die. Figure.4 showed the casted specimens.



Figure 1. Molten metal in the furnace crucible



Figure 2. Stirring of AA2024 with TiC



Figure 3. Pouring of molten metal



Figure 4. Casted specimens

2.2 Density Test

Density is a most predominant factor considered in various applications. To calculate the density of specimens, the mass of the specimen is observed using electronic digital weight scale. The volume is calculated depending on the diameter and height which is measured with the help of Vernier caliper. The specimens prepared for the density test is shown in the Figure.5. Below



Figure 5. Density Test Specimens

2.3 Hardness Test

ASTM E18 standard testing method was employed to know the hardness number of the specimen by using Rockwell hardness tester “B” scale. The type of indenter used was hardened steel ball having a dia of 1/16th of inch and the total load applied is 1000 N. The time of application of load is 15sec.

2.4 Tensile Test

The Figure.6 gives the dimensions of the tensile test specimens which is in accordance with ASTM E-8M. The test has been done in displacement control mode with a rate of 0.1 mm/min. The load and displacement were measured.

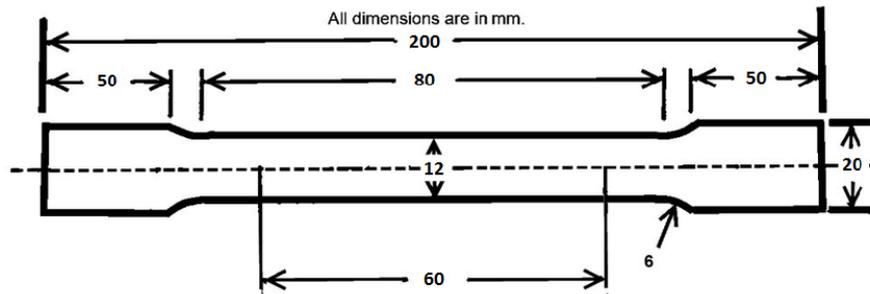


Figure 6. Tensile Test Specimen

3. Results and Discussion

3.1 Density Test and Hardness Test

The density test conducted on the specimens and it revealed that the density of the samples increase as expected on the addition of the reinforcement. The Figure.7. Shows that the maximum density was observed for 6% Titanium carbide reinforcement. The hardness of the material improved on the addition of TiC. The hardness value improved to a greater extent on the addition of 6% Titanium carbide with maximum hardness of 58 BHN. The slop of the curve shows further increase in the TiC might improve the hardness but not appreciably.

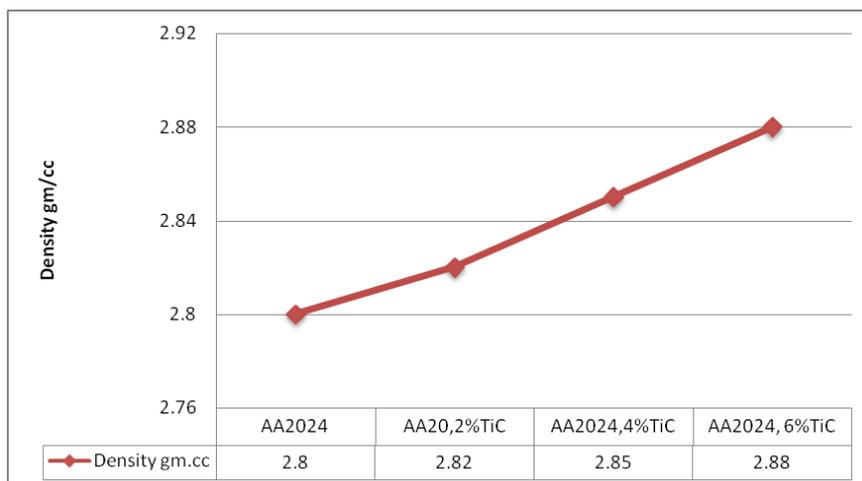


Figure 7. Variation of Density for different percentages of TiC

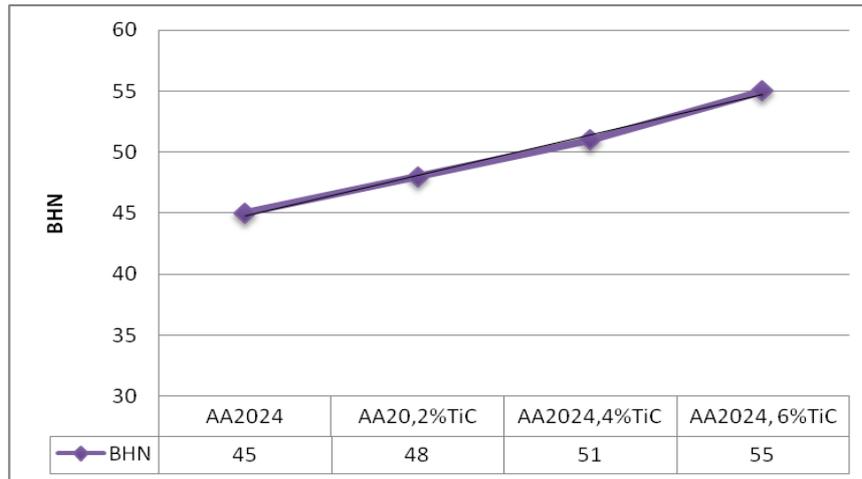


Figure 8. Variation of Hardness for different percentages of TiC

3.2 Tensile Test

The tensile test specimens after fracture are shown in the figures 9 and 10, revealed that the tensile strength increases with increase in weight % of Titanium carbide and % of elongation is decreased in increased % of TiC. It is also observed that Titanium carbide improved the yield strength of the material better than base Al 2024 alloy. Interfacial bonds of the material are affected because of the maximum stress experienced by the specimen. The ductility of the material decreases on the addition of the reinforcement materials. A greater reduction in ductility was observed on the addition of 6% Titanium Carbide. Percentage of elongation decreases in increasing the % of reinforcement.

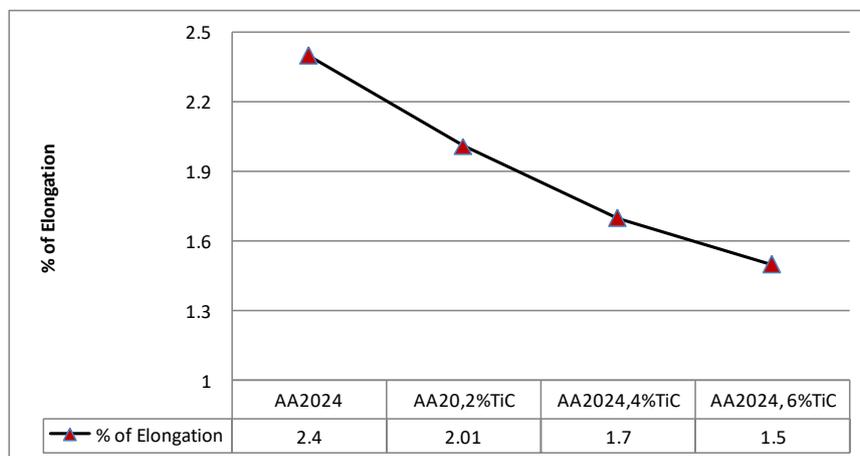


Figure 9. Percentage Elongation for different percentages of TiC

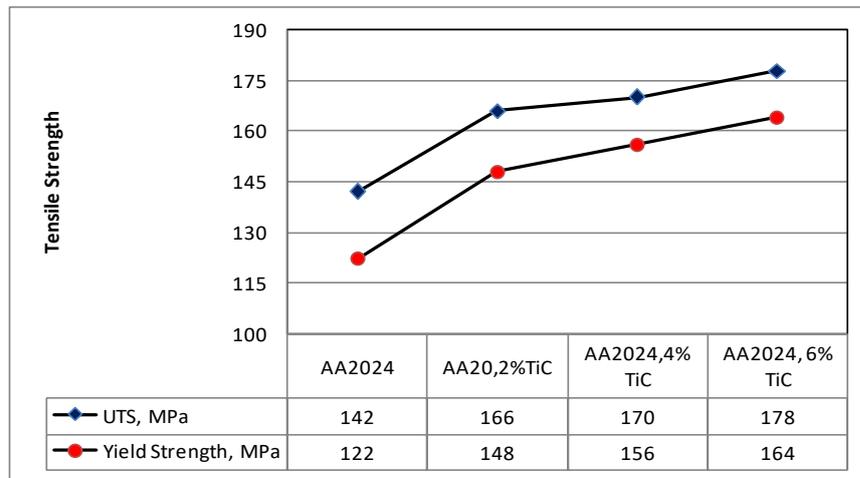


Figure 10. Strength variations for different percentages of TiC

3.3 Microstructure

The microstructure of AA2024 is shown in the Figure.11. The microstructure consists of inter metallic precipitates in a matrix of Dendritic Aluminum solid solution. No segregation or porosity was seen in the section. The microstructure of AA2024 with 2%, 4% and 6% Titanium Carbide are shown in the Figure.12. This also showed the uniform distribution of the TiC particles, because of the proper stirring action takes place during the casting process and also it observed from optical microscopy that grain refinement is increased by increasing the wt.% of TiC particles.

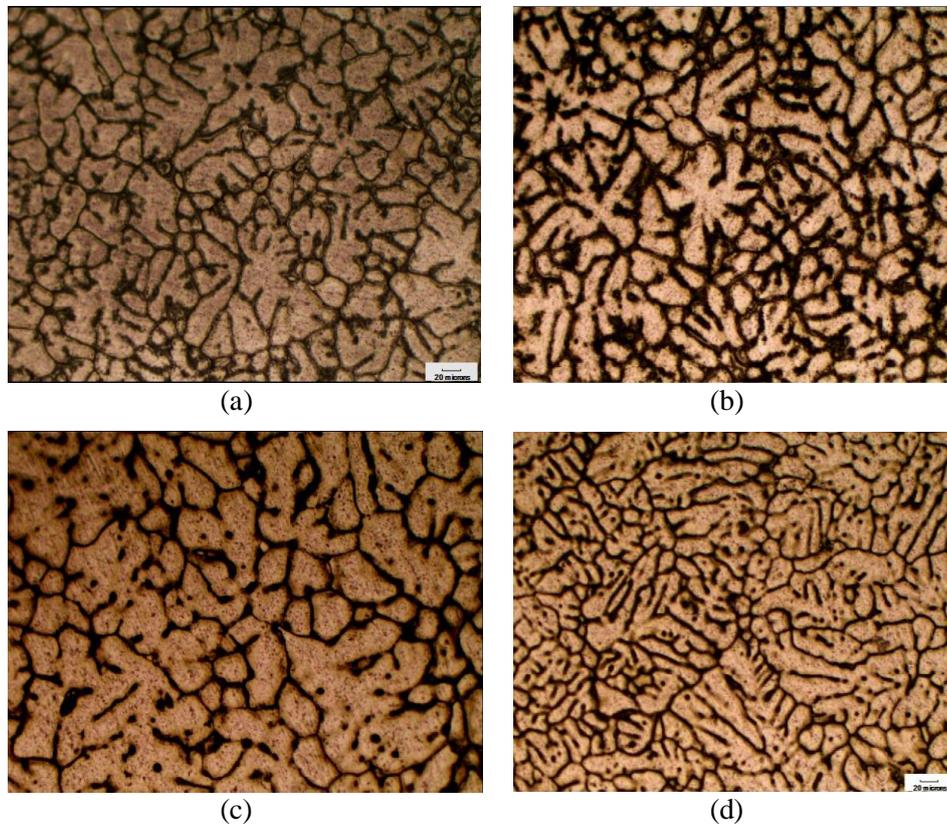


Figure 11. (a) Microstructure of AA2024, (b) .Microstructure of AA2024 with 2% TiC (c) Microstructure of AA2024 with 4% TiC (d) Microstructure of AA2024 with 6% TiC

4. Conclusion

The density of the material was observed to increase with the addition of reinforcement materials to the matrix material. Aluminum 2024 reinforced with Titanium Carbide is effective in increasing the tensile strength of the composite material. The optimum tensile strength was observed in the sample containing 6% Titanium Carbide by weight. Addition of the reinforcement materials result in a reduction in the ductility of the material. It is also observed that Young's modulus of the MMC is increased with the effect of TiC reinforcement in Matrix phase. From the microstructure it can be seen that the intermetallic precipitates are present and they are uniformly distributed across the matrix material.

5. References

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