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Comparative Study of Composites Reinforced With SiC and TiB_2

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Abstract

In this present work an effort has been made to fabricate and compare the properties of aluminium metal matrix composites. Two specimens were fabricated by adding 10 wt % of SiC and TiB_2 with aluminium metal matrix. The two specimens were fabricated using stir casting route with bottom pouring technique. Morphology of the cast composites reinforced with SiC 10 wt % and TiB_2 10 wt % were studied in detail by optical microscopy to analyze particle distribution in the aluminium metal phase. The hardness test was carried out to find out the hardness of the cast composites using Vickers hardness testing machine. The hardness test and its comparison show that the hardness value of SiC composite is higher than TiB_2 composite. Mechanical testing was carried out on the tensile samples prepared from the two cast composite specimens. From tensile test results it has been observed that the tensile strength of TiB_2 composite is 30 % higher than SiC composite. Wear test was carried out to study the wear resistance behavior of cast composites. Wear test analysis proves that the wear resistance behavior of TiB_2 composite is higher than SiC composite.

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Keywords: Metal matrix composite; SiC; Tensile strength; TiB_2;Wear;

1. Introduction

Composites are widely used in aerospace, defense and it in automotive industries because of its unique properties like high specific strength, wear resistance, high hardness, strength-to-weight, strength-to-cost, etc. [1]. Efforts had been taken to pioneer hard ceramic particulates like SiC, Al_2O_3 and B_4C into aluminum metal matrix. Literature study shows that among the reinforcements SiC is chemically Compatible with aluminum metal matrix and forms an adequate bond with the metal matrix without forming inter- metallic phase and has other benefits such as good thermal conductivity, required workability at low cost [2]. Long ago main focus was offered for the improvement of metal matrix composite with SiC in various weight percentages and importance was given to study

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it's mechanical, tribological, and machinability properties etc. Presently due to the need of engineering materials with elevated strength, improved wear resistance and superior temperature performance various reinforcements compatible with aluminum metal matrix are under research. Al_2O_3 is one of the widely used second reinforcement. But it has its own demerits like poor wetting behavior with aluminum and more weight percentage leads to increase in porosity [3]. Few works were carried out to introduce TiB_2 an outstanding reinforcement among all the other reinforcements with aluminum metal matrix. This is due to the fact that TiB_2 reveals outstanding features such as high melting point (2790°C), high hardness (86 HRA or 960 HV) and high elastic modulus ($530*10^3$ GPa) and good thermal stability. TiB_2 ceramic particle do not react with molten aluminum, thereby avoiding formation of brittle reaction products at the reinforcements-matrix interfaces. Also aluminum reinforced with TiB_2 is known for its high wear resistance property [4]. T.V. Christy in his paper, "A Comparative Study on the Microstructures and Mechanical Properties of Al 6061 Alloy and the MMC Al 6061/TiB_2/12_P" the composite Al-6061/TiB_2/12p was successfully produced by the in-situ reaction procedure. Strings as well as particulate agglomerates were present as distinct micro structural features of the composite. The manufactured Al-TiB_2 composite exhibited higher values of hardness, tensile strength and Young's modulus than the base alloy [5] Investigation of previous work revealed that, the main fabrication technique used was in-situ salt reactions. The stir cast aluminum matrix and its process parameters were thoroughly investigated by Pai, et. Al [6]. A new effort has been taken to fabricate composite reinforced with single reinforcement SiC and TiB_2 for a wt % of 10 using Stir casing route and a new technique of bottom poring method was adopted. This works deeply compare and analyze mechanical and tribological properties of both composite specimens, reinforced with SiC and TiB_2. Khairaldien's research shows a drop of strength at 15-20% weight percentage of silicon carbide due to the contact of SiC particle with the other and the increase in chance of more than two particle cluster together. Considering, this work % of reinforcement has been fixed (10% for SiC and TiB_2) [7]. This new effort clearly manifests the outstanding properties of SiC and TiB_2 in an aluminium metal matrix composite with respect to, hardness, tensile strength and wear.

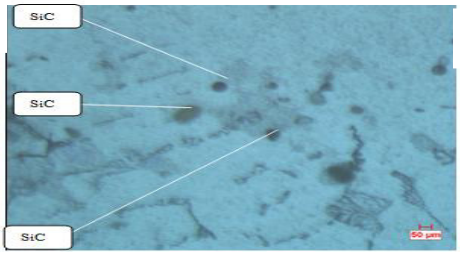
2. **Experimental Procedure**

Silicon carbide particles of average size of 25 microns were selected as reinforcement for the first specimen. Titanium di boride particles of average size of 10 microns were selected as reinforcement for the second specimen. The metal matrix phase is aluminum (6061 T6). The wt % of reinforcement both SiC and TiB_2 with metal matrix phase is 10%. SiC particles were preheated at 1000°C for 2 hours to improve the wettability by removing the absorbed hydroxide and other gases. TiB_2 is preheated up to 200°C. The furnace temperature was raised to 750°C to melt the matrix completely. At this stage the preheated SiC particles were added and mixed. 2 grams of magnesium is added in order to increase the wet ability. Mechanical stirring was carried out for 15 min at 350 rpm average stirring speed. The molten metal is poured into the mould by gravity casting. Similarly the second specimen reinforced with TiB_2 is fabricated. The dimensions of the specimens were 300 mm in length and 50mm in diameter. Morphology of different specimens was studied by optical microscopy. The hardness testing was carried out using (Matsuzawa MMT-X) Vickers hardness machine with 200gf for 10 seconds. Ten readings were taken with standard distance of 0.5mm from every indentation to achieve reliability in results. Diamond indenter is used. Four samples were made from each specimen to have high reliability in results. The tensile test was carried out using INSTRON tensile testing equipment. The specimens were made as per ASTM standards. A wire EDM machine was used to cut the specimens as per standards. The set up used to carry out wear test experiment was a pin-on-disc reciprocating wear testing machine. Specimens of 10mm width and 30mm length and breadth were cut by wire EDM, machined, and then polished to a surface roughness of less than one micron. The pins are made up of mild steel. Wear tests were conducted with a load of 50N and 70N respectively. The distance travelled by mild steel pin on the specimen prepared is around 720 m. The temperature range is from 35°C to 44°C with a frequency of 10Hz. After conducting all experiments the results and its values were tabulated. A comparative study was carried out between cast SiC and TiB_2 metal matrix composite.

3. **Result And Discussion**

3.1. Microstructure Analysis

The optical micrograph of Al/SiC and Al/TiB_2 MMCs is prepared using optical microscopy. Fig. 1(a) shows the micrographs of Al/SiC-10% which shows the presence of SiC particles and its distribution in the aluminium metal matrix. Fig. 1(b) shows the micrographs of Al/TiB_2-10% which shows the presence of TiB_2 particles and its distribution in the aluminium metal matrix. Micro structural analysis proves the presence of SiC particles in the first specimen and TiB_2 particles in the second specimen and its distribution in the metal matrix. The morphology of the TiB_2 particles is typically hexagonal or nearly spherical and there are clear interfaces between particles and 6061 matrix [5]. It can be seen in the micrograph of SiC content some SiC particles distributed evenly also some small particle agglomerate to form some particle clusters. The SiC particles are visible and the average size of particles is 25 microns. It can be seen in the micro graph of TiB_2 content the particles are evenly distributed and no particle agglomerate are noticed. This strong interface between the particle and 6061 matrix enhance mechanical properties.

a) 

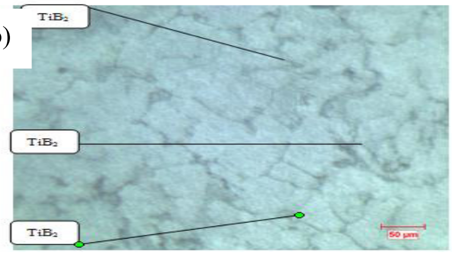
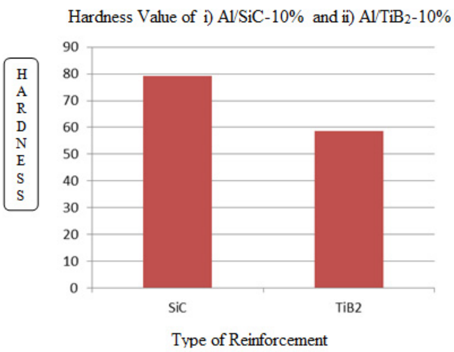
b) 

Fig. 1. (a) Optical micrograph of 10% SiC ; (b) Optical micrograph of 10% TiB_2.

3.2. Hardness test of Al 6061 reinforced with SiC and TiB_2

The average values are plotted in graph HV versus nature of reinforcements SiC and TiB_2 respectively. Graph sees Fig. 2 (a) shows that the hardness value of SiC is higher than TiB_2 composite specimen. In contrast an increase in hardness value was expected for TiB_2. This reduction in hardness value for TiB_2 content indicates a reduction in the work of indentation, which could be related to the distribution of residual tensile stresses in the ceramics. Also micro cracking may leads to drop in hardness value, because the work of indentation is decreased through the closing of micro cracks [8]. This could be the causes of reduction in hardness value when an increase was expected.

a) 

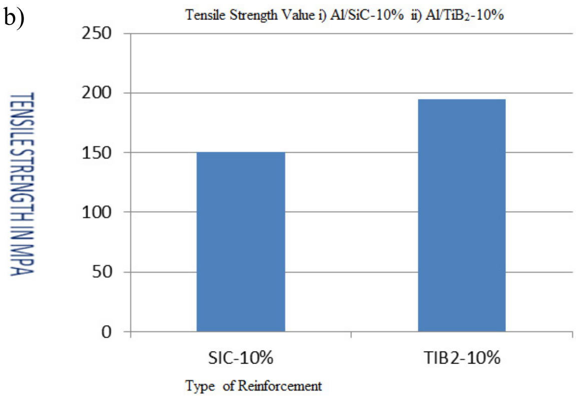
b) 

Fig. 2. (a) Comparative hardness chart; (b) Comparative tensile strength chart.

3.3. Tensile test

Tensile teats were carried out for SiC and TiB_2 composite specimens and the average values were tabulated in Table 1. The development in tensile property of the composites can be imputed to the contact between particles and dislocations; reinforcement particles operate as barriers to the movement of dislocations under the load, enhances higher tensile strength of composites. The tensile value of SiC composite which is 150.1 MPa reveals that there is increase in strength of composite than base alloy. This is due to the SiC particles which evenly distributed in the matrix and the interfacial bonding between particle and the matrix phase. The second specimen of TiB_2 composite exhibits higher strength than SiC composite. The replacement of SiC with TiB_2 or the effect of TiB_2 exhibits 30% increase in tensile strength of the composite. This can be attributed to the grain refinement and coordination mechanism which can retard the crack propagation during tensile test as TiB_2 is a common grain refiner for aluminum alloys [8]. This comparative study concludes TiB_2 composites have higher tensile strength than SiC. Fig 2(b) shows the comparison of tensile strength of SiC with TiB_2 composite which clearly depicts the 30% increase in tensile strength of TiB_2 composite.

Table 1. Tensile test values

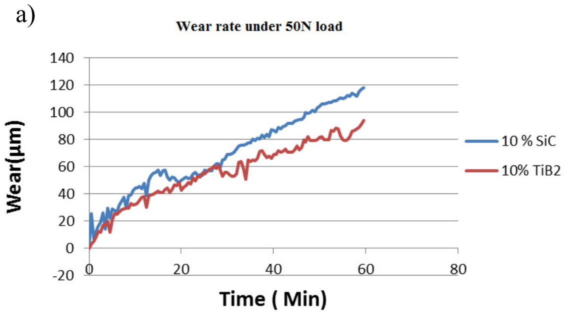
Type of reinforcements	Tensile strength (MPa)
Al/SiC-10%	150.1
Al/TiB_2-10%	195.0

3.4. Wear test analysis

3.4.1. Wear test analysis of SiC and TiB_2 composite under a load of 50N

Wear test was carried out separately in order to evaluate the wear resistance of the composites and a graph (Fig 3(a) & Fig 4(a)) is plotted using experiment results. Also the specimens were weighed before and after the experiment and wear mass loss was tabulated. Test was carried out for 60 minutes with a load of 50N and the wear value of SiC-10% and TiB_2 10% was 118.11µm and 94.03 µm respectively as shown in Fig 3 (a). This show wear resistance property increases by 20% when SiC is replaced by TiB_2 as shown in Fig 4(a). Table 2 depicts the wear mass loss of the SiC composite is 66.2 mg and the wear mass loss of the TiB_2 composite is 41.3mg. This is due to the hardness, high stiffness and thermodynamic stability of TiB_2 particles and replacement of SiC with TiB_2 composite can greatly improve wear resistance of composite.

a)



b)

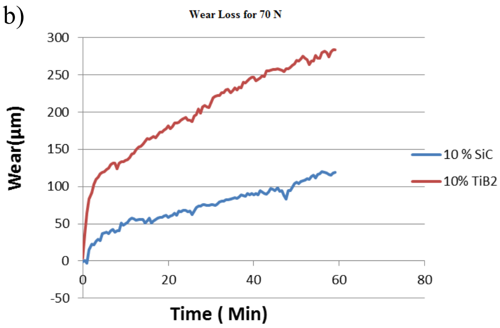


Fig..3. (a) Wear rate under 50N load; (b) Wear rate under 70N load

Table 2. Wear mass loss under 50N load

Test Condition Weight (mg)	10% SiC reinforcement	10% TiB_2 reinforcement
Before Test	20434.0	17599.5
After Test	20367.8	17558.2
Wear mass loss in (mg)	66.2	41.3

Table 3. Wear mass loss under 70N load

Test Condition Weight (mg)	10% SiC reinforcement	10% TiB_2 reinforcement
Before Test	16652.3	20367.8
After Test	16616.0	20233.2
Wear mass loss in (mg)	36.3	134.6

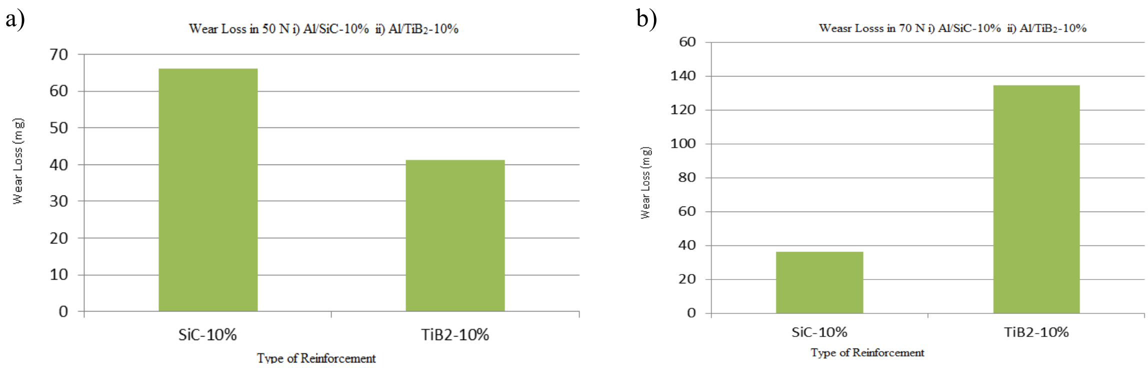


Fig.4. (a) Comparative wear mass loss chart for 50N load; (b) Comparative wear mass loss chart for 70N load

3.4.2. Wear test analysis of SiC and TiB2 composite under a load of 70N

Wear test was carried out separately in order to evaluate the wear resistance of the composites and a graph (Fig 3(b) & Fig 4(b)) is plotted using experiment results. Also the specimens were weighed before and after the experiment and wear mass loss was tabulated. Test was carried out for 60 minutes with a load of 70N and the wear value of Sic-10% and TiB2 10% was 118.837µm and 284.03 µm respectively as shown in Fig 3 (b). This show wear resistance property SiC is 140% higher TiB2 composite as shown in Fig 4(b). Table 3 show the wear mass loss of the SiC composite is 36.3 mg and the wear mass loss of the TiB_2 composite is 134.6mg. This is an adverse result may be due lack of reinforcement in the total volume of wear test specimen or specific wear test area. It can be due to movement of TiB2 particles during solidification and if wear test specimen is cut from top most portion of the casting.

3.4.3. Wear mass loss on mild steel pins used for wear test of composites.

Table 4 shows the wear mass loss of mild steel pins used to carry out wear test. Tests were conducted under 50N and 70 N respectively. The wear mass loss after the test is measured and tabulated. The wear mass loss of pin under 50N load for SiC is 4.1mg and TiB_2 composite is 7.2 mg. Similarly the wear mass loss of pin under 70N load for SiC is 5.8mg and TiB_2 composite is 9.9 mg. As the wear mass loss of mild steel pins for both at 50N and 70N load wear test which are conducted against TiB_2 composite was higher this simply proves the high wear resistance property of TiB_2 composite than SiC composite. Fig 5 & 6 Shows the wear mass loss of mild steel pins which were used to conduct wear test against SiC and TiB_2 composite.

Table 4. Wear mass loss of mild steel pins

Test conditions	Before Test	After Test	Wear mass loss
SiC-10%(50N) Pin 1	21441.6	21437.5	4.1
SiC-10%(70N) Pin 2	20789.7	20783.9	5.8
TiB_2-10% 50N) Pin 3	19690.8	19683.6	7.2
TiB_2-10% 70N) Pin 4	19692.3	19682.4	9.9

4. Conclusion

1. The Al/SiC and Al TiB_2 metal matrix composites were successfully fabricated using stir casting route.
2. Micro Structural analysis shows the presence of SiC and TiB_2 and its distribution in the metal matrix.
3. It has been concluded from hardness test that hardness value of SiC is higher than TiB_2 composites
4. This comparative study concludes TiB_2 composites have higher tensile strength than SiC. The replacement of SiC with TiB_2 or the effect of TiB_2 exhibits 30 % increase in tensile strength of the composite.
5. It has been proved from wear analysis that TiB_2 particles increase the wear resistance behavior of hybrid aluminum metal matrix. It is concluded that
   - Wear resistance property increases by 20% when SiC replaced by TiB_2
   - Wear mass loss of mild steel pins of both the tests at 50 N and 70 N load conducted against TiB_2 composites was about 50% higher than SiC composite.

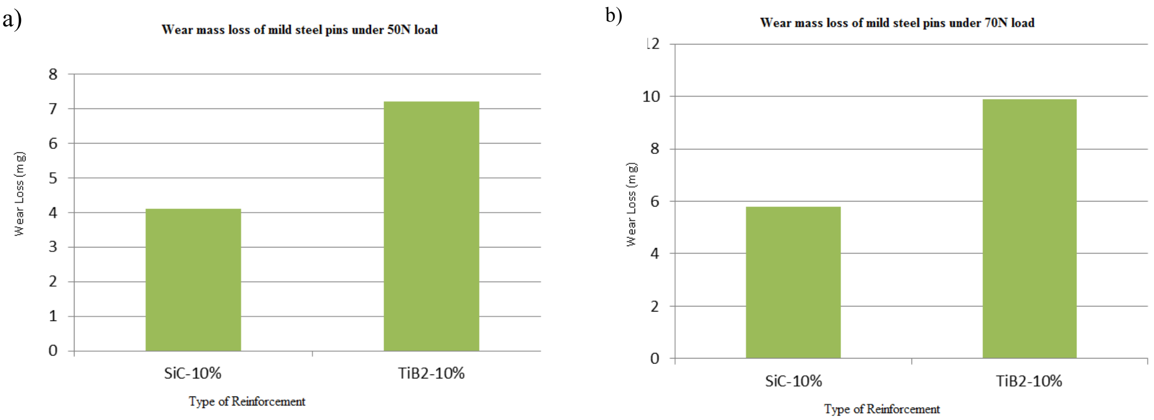


Fig.5. (a) Comparative chart of wear mass loss of mild steel pins under 50N load; (b) Comparative chart of wear mass loss of mild steel pins under 70N load

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