



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

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International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

**Volume 9, Issue 10, October 2020**

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 7.512**



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# The Effect of Microstructure, Mechanical and Wear Properties of Al-1.2Mn-0.12Cu Reinforced TiC Composites

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**ABSTRACT:** In the present study, Al3003 percentage of TiC (3%, 5% and 9%) is fabricated by the liquid metallurgy and studied for a microstructure, mechanical and the wear properties. Microstructure revealed even dispersal of TiC alloy is reinforced with different particles in the matrix resulting in an enhancement in mechanical and wear properties compared to as-cast 3003 alloy. Fractography surfaces of the as-cast alloy and its composites were examined using Optical and Scanning electron microscope. Al3003 alloy+ 3% TiC composites showed good mechanical properties followed by Al3003 alloy+ 5% TiC composites and Al3003 alloy + 9% TiC.

**KEYWORDS:** TiC, A3003 alloy, Microstructure, Hardness, Tensile, Fractography and Wear

## I.INTRODUCTION

Today in Modern day innovation there is a regularly expanding request in materials which accomplishes great quality, strength, solidness, and thickness. However, customary solid materials have restrictions in accomplishing these blends. Compound is a strong arrangement of at least two materials with a solitary strong stage microstructure while in a composite the two segments are isolated by an unmistakable interface at the microscopic and macroscopic structure. Alloys can be heterogeneous or homogeneous whereas composites are generally heterogeneous. Also, alloys can exhibit both isotropic and anisotropic properties whereas composites are generally anisotropic in nature. The physical properties such as density, Young's modulus and thermal conductivity may not differ from those elements, but in the case of composites, the addition of reinforcement into the metal grid shows a considerable increase in the above-mentioned physical properties. Composites give better stiffness and have a higher strength to weight ratio. A wider range of reinforcement materials to use in composites hence they have a broad range of properties. This project aims to design and develop an aluminium-based MMC to suit the requirements of aircraft materials. In this direction, an exhaustive literature review has been undertaken to develop a trail model of MMC. Subsequently, the testing methodologies being required to experimentally confirm the various properties are identified. In the end, the possible design of a new MMC is proposed for fabrication and validation. The word "composites" literally means "made of several parts". Composite materials are planned or regularly happening materials created utilizing at any rate two constituent materials with basically special physical or invention properties when stood out from the system which remain autonomous and specific at the naturally visible or microscopic scope inside the completed structure. Composites are known for their low density with high strength, stiffness, thermal stability, and improved fatigue properties and wear resistance. Many composites are developed by numerous researchers by combining various reinforcements such as flyash, SiC, B<sub>4</sub>C, Al<sub>2</sub>O<sub>3</sub> and many more [1-5]. In the current examination Al3003 compound was picked as grid material as a result of its more extensive aviation and automotive applications in ventures, similarly as the recreational things. At present little details is obtainable in the Alumina strengthened Al3003 amalgam composites. As such, the current assessment attempts to incorporate the Alumina reinforced Al3003 combination composites by blend tossing methodology. Later these composites will be depicted similar to their Optical Microscope, SEM considers, hardness, wear and the mechanical properties.

**II. EXPERIMENTAL PROCEDURE**

Stir casting has been used by several researchers to fabricate composites especially metal based composites in order to develop castings with less porosity [6-7]. In the current study, the Al3003-TiC reinforced Al-MMC's is produced in the stir casting process. While the fabrication of the Al3003/TiC composite. TiC of particle size of 15µm was selected after conducting sieve analysis for the present investigation. Two different composites of different reinforcement percentage (3%, 5%, 9%) weight percent were fabricated by the stirring process. The casting set up assembly is shown in fig below.

**Table 1: Chemical composition of Al3003 alloy (weight percentage)**

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others	Balance
0.60	0.70	0.20	1.2	1.0 -1.5	-	0.10	-	0.05	Aluminium



**Figure 1: Stir casting set-up assembly**

The composite made by this examination will contain fluctuating rate bit of TiC (3 and 5 percent) throughout formation of the Al3003/TiC composite TiC of particle sizes of ~15µm were picked for the current assessment. In this examination plans to look at the effect of assortment of the rate structure of Al3003/TiC composites to imagine the wear and the Mechanical Properties of MMCs and differentiate the result.

**Table 2: Designation of TiC Reinforced Alloy**

S/No	Alloy/Composite	Designation
1	As-Cast (Al3003 alloy)	Ac
2	Al3003 alloy + 3%TiC	3T
3	Al3003 alloy + 5%TiC	6T
4	Al3003 alloy + 9%TiC	9T

**III. EXPERIMENTAL SETUP**

**Microstructural Characterization:**

The micro-structure is the one of most important parameter which affects the physical properties of the alloy/ metal. By knowing the microstructure, we can predict the behaviour of a component made of a particular material. This is also important while predicting the failure of a component in certain conditions. The microstructural characterization was carried out using SEM

#### Hardness Test:

The Vickers hardness test is used in the context of the micro hardness test load range to assess the hardness of a material. However, the hardness test is also used to test thin layers such as coatings or to solve the problems of fragile and cracking materials.



Figure 3: Vickers Hardness Tester

#### Wear Test:

The Dry sliding wear tests were coordinated by ASTM-G99 norms. The wear rate relied upon the typical estimation of 3 tests. Loads of 10N, 20N and 30N at a sliding pace of 1.5m/sec and sliding detachment of 1802m.



Figure 4: Pin on Disc Wear

### IV. RESULTS AND DISCUSSIONS

#### 4.1 Microstructure analysis of A3003 alloy and its composites

Figure 4.1 shows the Scanning Electron Microscope images of A3003-TiC MMCs, where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 6113 alloy + 9% fly ash (e) EDAX taken on Aluminium 6113 alloy + 6% TiC. From the Fig 4.1(a to e) we can see the even dispersal of Titanium Carbide (TiC) in the Al3003 matrix with least porosity or any casting defects in the Al3003 alloy and its composites. From the Figure 4.1(a) we can see few TiC particles distributed in A3003 matrix. Compared to Figure 4.1(b) and (c), Figure 4.1(d) shows more TiC particles distributed in A3003 matrix. Figure 4.1(e) shows EDAX analysis of Aluminium 6113 alloy + 9% fly ash which confirms the presence of TiC particles. These observations are in accord with several investigators [8-9].

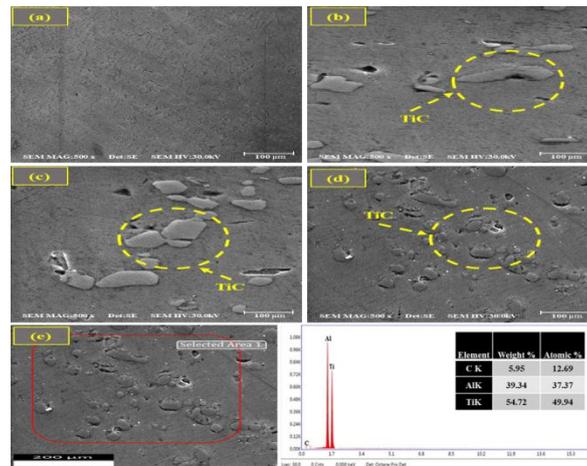


Figure 4.1: Microstructure Characterization of A3003-TiC MMC's using Scanning Electron Microscope, where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 6113 alloy + 9% fly ash (e) EDAX taken on Aluminium 6113 alloy + 6% TiC

#### 4.2: Hardness test results of A3003-TiC MMC's

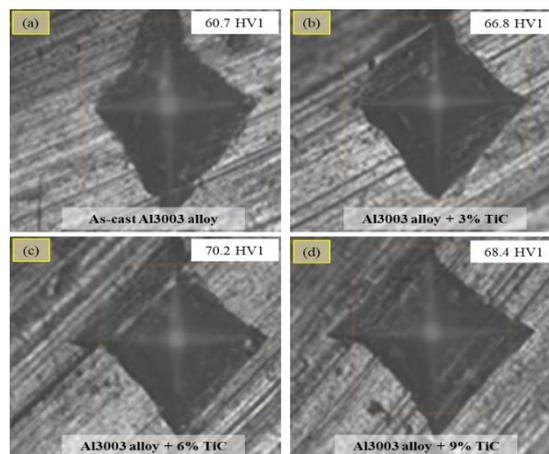


Figure 4.2: Vickers Micro hardness test optical microscope images of A3003-TiC MMC's, where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 6113 alloy + 9% fly ash.

Table 4.1: Hardness test values of A3003-TiC composites

S/No	Alloy/Composite	Designation	Hardness			% Improvement in Hardness
			Diagonal X(mm)	Diagonal Y(mm)	VHN	
1	As-Cast (Al3003 alloy)	A3003	0.115	0.114	60.7	----
2	Al3003 alloy + 3% TiC	A3003-3T	0.127	0.123	66.8	10.04
3	Al3003 alloy + 6% TiC	A3003-6T	0.126	0.127	70.2	15.65
4	Al3003 alloy + 9% TiC	A3003-9T	0.122	0.120	68.4	12.68

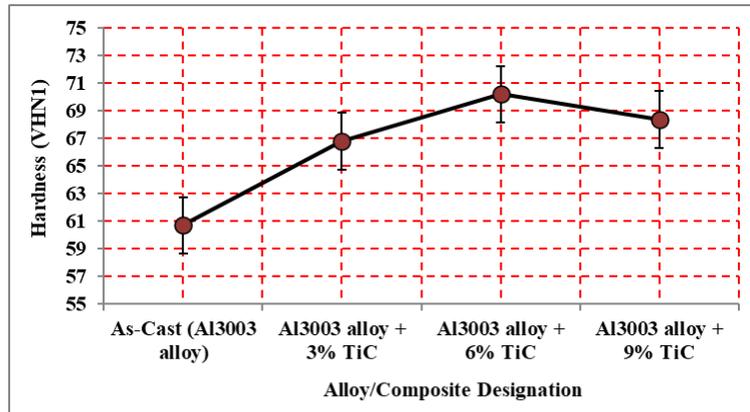


Figure 4.3: Hardness test values of A3003-TiC MMC's

Figure 4.3 expounds the hardness test results of Aluminium 3003-TiC MMC's. From Figure 4.3 it is found that hardness increases with increase in TiC particles in the A13003 matrix material. As compared to As-Cast (3003 alloy), Al 3003 alloy + 3% TiC increase in hardness of 6.1 VHN (10.04%), Al 3003 alloy + 6% TiC increase in hardness of 9.5 VHN (15.65%) and Al 3003 alloy + 9% TiC increase in hardness of 7.7 VHN (12.68%). From the figure we can observe that as the reinforcement percentage of TiC increases upto 6 % there is an increase in hardness, once the reinforcement is increased further i.e., from 6 % to 9 % there is a drastic decrease in hardness. This may be due to the clustering of TiC in the A3003 matrix. From the figure we can observe that as the percentage of TiC is increased there is an increase in hardness of composite. Similar observations were made by several researchers [10-11].

#### 4.3: Tensile test results of A3003-TiC MMC's

Figure 4.4 expounds the tensile test results (UTS) of Aluminium 3003-TiC MMC's. From Figure 4.3 it is found that strength increases with increase in TiC particles in the A13003 matrix material. As compared to As-Cast (3003 alloy), Al 3003 alloy + 3% TiC increase in strength of 11 MPa (9.17%), Al 3003 alloy + 6% TiC increase in strength of 19 MPa (24.16%) and Al 3003 alloy + 9% TiC increase in strength of 18 MPa (15.00%). From the figure we can observe that as the reinforcement percentage of TiC increases upto 6 % there is an increase in strength , once the reinforcement is increased further i.e., from 6 % to 9 % there is a drastic decrease in strength . This may be due to the clustering of TiC in the A3003 matrix. From the figure we can observe that as the percentage of TiC is increased there is an increase in strength of composite . Similar observations were made by several researchers [12-13].

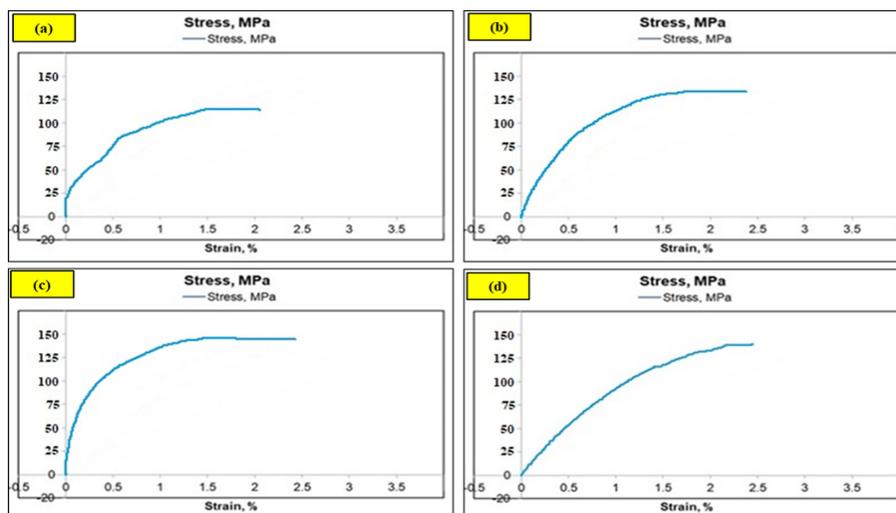


Figure 4.4: Stress Strain curve of A3003-TiC MMC's, where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 3003 alloy + 9% TiC.

Table 4.2: Tensile test values (UTS) of A3003-TiC composites

S/No	Alloy/Composite	Designation	Ultimate Tensile Stress (UTS)		% Improvement in UTS
			Strain rate (mm/s)	UTS (MPa)	
1	As-Cast (Al3003 alloy)	A3003	0.50	120	----
2	Al3003 alloy + 3% TiC	A3003-3T	0.50	131	9.17
3	Al3003 alloy + 6% TiC	A3003-6T	0.50	149	24.16
4	Al3003 alloy + 9% TiC	A3003-9T	0.50	138	15.00

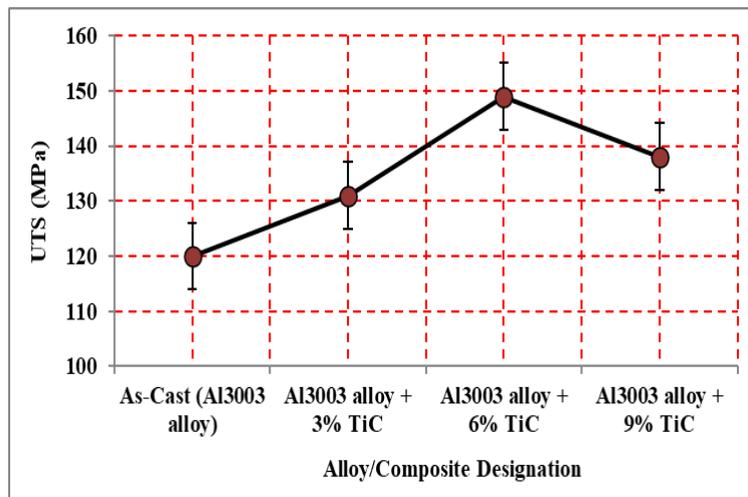


Figure 4.4: Tensile test values (UTS) of A3003-TiC MMC's

4.4: Fractographic analysis of A3003-TiC MMC's

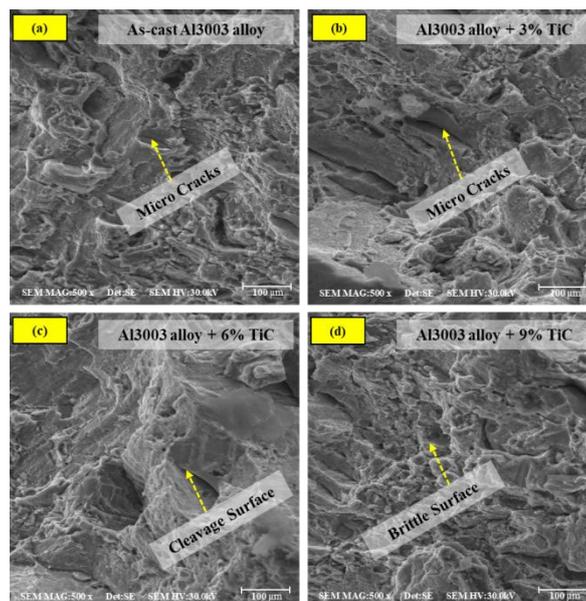


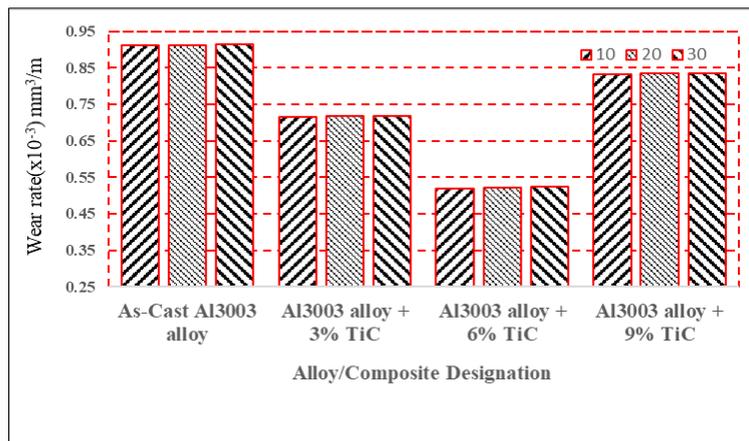
Figure 4.5: Tensile surface Fractographs of A3003-TiC MMC's, where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 6113 alloy + 9% fly ash.

Figure 4.5 shows the Tensile surface fractographs of A3003-TiC MMCs ,where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 6113 alloy + 9% fly ash. Figure 4.5 (a) shows the fractograph surface with few microcracks in them along with alpha dendrites. Figure 4.5 (b) and (c) shows the fractograph surface with few microcracks in them along with cleavage surfaces. Figure 4.5 (d) shows the fractograph surface with few microcracks in them. Overall, it can be analysed that as-cast alloy undergoes ductile fracture and A3003-TiC composites shows brittle fracture. Similar observations were made by several researchers [14-15].

**4.5: Wear test results of Al300- TiC MMC's**

**Table 4.3: Wear test values of Al3003- TiC composites**

Wear rate of A6113-Fly ash composites				
S/No	Load(N)	10	20	30
1	As-Cast Al3003 alloy	0.9112	0.9129	0.9138
2	Al3003 alloy + 3% TiC	0.7162	0.7175	0.7189
3	Al3003 alloy + 6% TiC	0.5201	0.5228	0.5253
4	Al3003 alloy + 9% TiC	0.8325	0.8341	0.8353



**Figure 4.6: Wear rate (mm³/m) v/s Load (N) of A3003-TiC composites**

From Figure 4.6 we can see that as the load increases the wear rate increases .Highest wear rate is for Al3003 alloy i.e.  $0.9112 \times 10^{-3} \text{ mm}^3/\text{m}$  for 10N and  $0.9138 \times 10^{-3} \text{ mm}^3/\text{m}$  for 30N. Moderate wear rate is found for Al3003 alloy + 3% TiC i.e.  $0.7162 \times 10^{-3} \text{ mm}^3/\text{m}$  for 10N and  $0.7189 \times 10^{-3} \text{ mm}^3/\text{m}$  for 30N. Followed by Al3003 alloy + 9% TiC i.e.  $0.8325 \times 10^{-3} \text{ mm}^3/\text{m}$  for 10N and  $0.8353 \times 10^{-3} \text{ mm}^3/\text{m}$  for 30N. Least wear rate is found for Al6113 alloy + 6% TiC i.e.  $0.5201 \times 10^{-3} \text{ mm}^3/\text{m}$  for 10N and  $0.5253 \times 10^{-3} \text{ mm}^3/\text{m}$  for 30N. TiC strengthens the matrix .Reinforcement materials acts as load bearing and protect matrix from wearing out [16-18].

#### 4.6: Wear Surface Morphology of Al3000- TiC MMC's

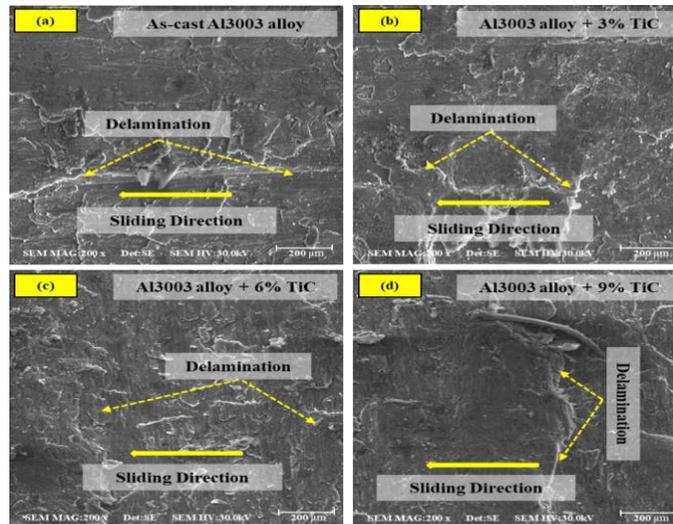


Figure 4.7: Wear surface Morphology of A3003-TiC MMC's, where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 6113 alloy + 9% fly ash.

Figure 4.7 shows the Wear surface Morphology images of A3003-TiC MMCs, where (a) As-cast Aluminium 3003 alloy (b) Aluminium 3003 alloy + 3% TiC (c) Aluminium 3003 alloy + 6% TiC (d) Aluminium 6113 alloy + 9% fly ash. From the Figure 4.1 (a) we can see more delamination surface which is due to the lower hardness and higher wear rate due to the absence of reinforcing material i.e., TiC as shown in section 4.1 and 4.5. Moderate delamination of wear surface can be found out in Figure 4.1 (b) followed by Figure 4.1 (d). Least delamination was found out in Figure 4.1 (c). These observations are in accord to Samal [19-20].

#### V.CONCLUSION

From the tests to understand the mechanical behaviour of TiC reinforced Al3003 composites of different weight fractions of the reinforcement, it was found that:

(i) The Optical Micrographs of polished specimens, the following was observed:

- The spreading of TiC is found to be even in Al3003 alloy matrix
- The TiC Particles acted as virtuous moistening with the Al3003 matrix which added to the enhancements of the mechanical and wear properties.

(ii) As the percentage of TiC particles increases in the matrix the hardness of Al3003 alloy increases gradually as the reinforcement percentage increases upto 6 % and there is a slight dip in hardness when percentage increases to 9 %. The dip in hardness may be due to clustering of TiC particles in A3003 matrix. Also, improvement in hardness is due to fact that TiC particles acts as load bearing materials.

(iii) As the percentage of TiC particles increases in the matrix the ultimate tensile strength UTS of Al3003 alloy increases upto 6 % and there is a slight dip in strength when percentage increases to 9 %. The dip in strength may be due to clustering of TiC particles in A3003 matrix. Also, improvement in strength is due to fact that TiC particles acts as load bearing materials

(iv) Wear rate of the A3003 reinforced composites is less than that of as-cast A3003 alloy. Highest wear rate is for Al3003 alloy, moderate wear rate is for Al3003 alloy + 3% TiC and least wear rate is for Al3003 alloy + 6% TiC.

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