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Tribological and Mechanical Characterization of Aluminum Metal Matrix Composites

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Abstract

Many researchers analyzed the wear characteristics and mechanical properties of Aluminium metal Metal Matrix Composites (AMMC) with Silicon Carbide (SiC) reinforcement however not abundant work has been reported on analyzing the wear characteristics of AMMC with pigment (TiO_2) reinforcement material. A try is created to fabricate Metal Matrix Composite with metallic element as matrix material and TiO_2 as reinforcement through stir casting methodology and to investigate the wear and tear and mechanical characteristics. Aluminium 6061 and variable weight fractions as 0.5, 1 and 1.5% of nanoTiO_2 was fancied through the technique of Stir followed by Die Casting. Subsequent analysis on wear characteristics exploitation Pin on Disc and mechanical characteristics viz. Vickers micro hardness, tensile, compressive and surface roughness tests were carried out. The results showed improved wear and mechanical characteristics for 1% reinforcement material.

Keywords: Aluminium Metal Matrix Composites, Stir Casting, Titanium Dioxide, Mechanical characteristics, Wear

1. Introduction

Composite material may be a material suspended with two or additional divergent parts (matrix phase and reinforcing phase) and having bulk properties significantly numerous from those of any of the constituents. The new material may be chosen for several reasons: frequent examples embody materials are stronger, lighter or cheap once compared to standard materials. Numerous regular materials like metals, alloys and polymers assorted with additives as well have a little quantity of discrete phase in their structure, nevertheless they are not considered as composite materials in view of the fact that their properties are alike to those of their base constituents.[1] Encouraging properties of composites materials are high stiffness and high strength, low density, high temperature constancy, high electrical and thermal conductivity, corrosion resistance, improved wear resistance etc. Metal Matrix composites are composed of a tinny matrix and a distributed ceramic or tinny part. Metal matrix composites, presently though generating associate degree in depth notice in analysis fraternity, are not as extensively in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those gettable by their chemical compound counterparts.

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Titanium, Aluminum and magnesium are the fashionable matrix metals presently in trend, which are predominantly helpful for craft applications. If metallic matrix materials have to provide high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites will be more than most alloys. It is realized that the nano particles have high surface to volume magnitude relation, the basic factor, which has improved the material performance. Various mixtures of matrices and reinforcements have been tried however work on MMNC began in the late 1950s. However, MMNC technology is still in the early stages of development and other necessary systems doubtless can emerge.[2,15–18] Numerous metals have been used as matrices. The most important are metal, titanium, magnesium and copper alloys. Many methods are available to fabricate the composites, depending on the final part geometry and geometry requirements. Aluminium MMCs area unit largely created by casting, powder metallurgy, in situ development of reinforcements, and foil-and-fiber pressing techniques. Stir casting is one of the foremost extensively used processing ways, due to the benefits of being simple, relatively cheap to turn out and also the ease within the scale-up to massive quantities.

Aluminium2024 matrix reinforced with TiO_2 will increase the hardness, elastic modulus and yield stress effectively[1]. The microstructure and tribological properties of Al-SiC based composite was investigated by Ali Mazahery et al.[2,6] by proper choice of method parameter such as gushing temperature, stirring speed, stirring time, pre-heated temperature of reinforcement.

Aluminium-silicon alloys and aluminium based metal matrix composites have found application in the manufacture of assorted automotive engine parts like cylinder blocks, pistons and piston insert rings where adhesive wear (or dry slippery wear) is a predominant method[3,8].

In the present study, to meet the requirements of various industries, aluminum6061composites reinforced with 0.5, 1, 1.5 volume fractions of TiO_2 nanoparticles are fabricated via stir casting. Wear and mechanical characteristics are analyzed.

2. Experimental Procedure

The Stir casting method was used to prepare nano composites and the experimental setup is shown in Figure 1(a) and Figure 1(b).

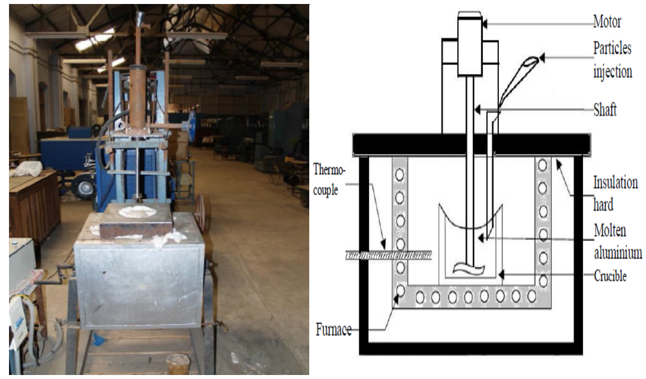


Figure 1(a). Stir casting setup 1(b) Layout

The Al alloy pieces were heated to 1100°C in a graphite crucible. The nano TiO_2 reinforcement particulates and magnesium (2%wt) are preheated for 30 minutes. Magnesium is added to promote wettability. Aluminium degassing tablets are added in the powdered form to remove the bubbles formed during the process. The heated slurry was stirred at 310 rpm for 10 minutes using a three blade mild steel impeller to ensure uniform incorporation of the nano TiO_2 particles into the Aluminium matrix.

The three blade mild steel impeller was coated with alumina powder to avoid iron contamination of the molten Al metal. The impeller was placed just 20 mm above the bottom of the graphite crucible, and the blades of the impeller (tilted at an angle of 45°), when rotated, covered a relatively large area of the crucible base. This design prevented the heavier Nano TiO_2 from settling when the melted slurry was stirred for 5 minutes.

Furthermore, stirring at an optimized speed of 310 rpm created a vortex in the melt, and this effectively enhanced the distribution of the particles. This stirring process was used to ensure the homogeneity of the melted slurry. The melt, with incorporated Nano TiO_2 particles, are poured in to a mould rod of length 200mm and diameter 20mm.

3. Results and Discussion

3.1 Wear testing

The Pin on Disc tester is used for a fast and simple method of kinetic friction and slippy wear activity. It measures the friction and sliding wear properties of dry or greased surfaces of a selection of bulk materials and coatings. The Pin on Disc wear testing apparatus consists of a rotating disc, EN-31 steel and the Al-nano TiO_2 composite pin of the fabric to be tested is shown in Figure 2(a) and Figure 2(b). The pin surface can conjointly be wear and friction tested.

Figure 2(a). En-31 steel disc.

Figure 2(b). Pin specimen.

The normal load, rotational speed, and the wear track diameter are set prior to the pin on disc wear test. Dry sliding wear tests were conducted using a pin-on-disc tester as per the ASTM G-99 standard. Pin specimens of diameter 8mm and length 30 mm were machined from the casted rods. A pin holder loaded the stationary pins vertically onto a rotating En-31 steel disc. A normal load of 9.81 Kg was applied using dead weights at 1273 rpm. For each sliding condition, 492 seconds of run were carried out. At the end of 492 seconds, the pins were carefully cleaned and weighed using a sensitive electronic balance with an accuracy of ±0.001 mg to determine the weight loss. The following table.1 shows the mass loss for the applied load for Al-Nano TiO_2 Composites and interprets that increasing the weight percentage of nano TiO_2, reduces the wear and for 1.5 weight % of TiO_2 it is increasing.

Table 1. **Weight loss during wear testing**

% of nano TiO_2	Weight of the pin during wear testing (gm)		Difference (gm)
	Before	After	
0.5	4.269	4.262	0.007
1	4.267	4.265	0.002
1.5	4.449	4.445	0.004

The following graphs (Figure 3 and Figure 4) depict the wear properties for various weight percentage of TiO_2 for the duration of 492 seconds.

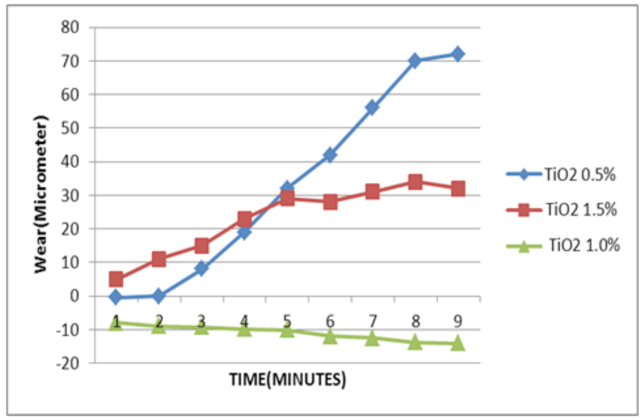


Figure 3. Wear rate of Al-TiO_2 composites.

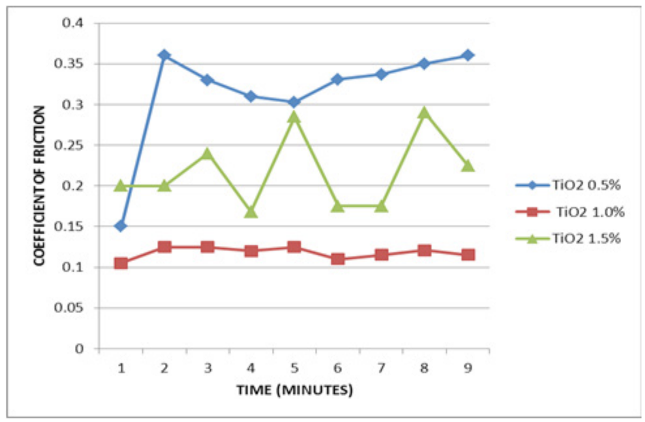
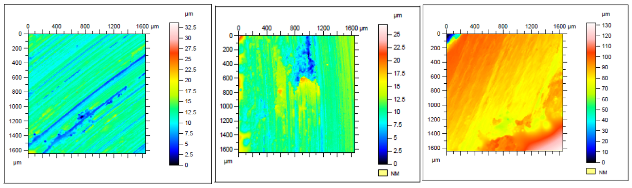


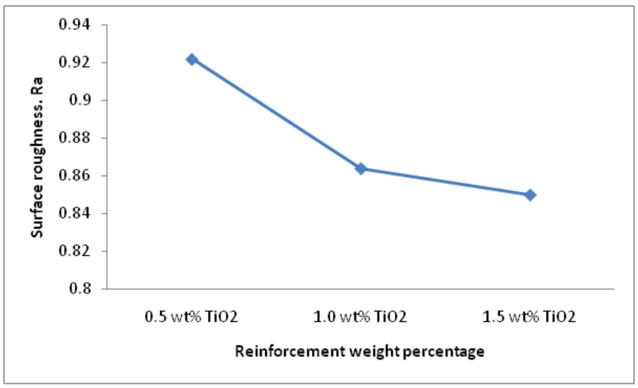
Figure 4. Coefficient of friction for Al-TiO_2 composites.

3.2 Surface roughness

Surface roughness affects the wear rate. The higher the roughness, the higher are the wear rate. The hardness is inversely proportional to the wear rate therefore the fabric with a lower hardness reduces the wear resistance because of the mutual abrasion between the counter material and therefore the wear surface of the specimen[4,7]. Increasing the volume fraction of TiO_2 nano particles within the composite reduces its wear rate. Figure 5(a), Figure 5(b) and Figure 5(c) shows the non-contact surface roughness of 0.5, 1 and 1.5 weight proportion of nano TiO_2 bolstered metal metal matrix composites. Figure 5(d) shows the surface roughness Ra values and depicts that the increase in percent weight of nano TiO_2 reduces the surface roughness.



. (a) (b) (c)



(d)

Figure 5. (a),(b),(c) Non contact surface roughness values of the composite with 0.5, 1, 1.5 weight percentage of TiO_2. (d) Surface roughness, Ra values for 0.5, 1, 1.5 weight percentage of nanoTiO_2.

3.3 Hardness testing

Vickers micro Hardness is calculated by forcing an indenter into the surface of the sample. It uses a 136° square pyramid indenter, which produces a square indentation in the specimen, rather than a spherical or conical indenter, which Norman Rockwell and Brinell hardness techniques use. Vickers hardness test was carried out for measuring the hardness of aluminum with Nano titanium dioxide strengthened metal matrix composites. Indenter load is kept at 0.5 kg. The indentation is then measured with a microscope across the diagonals of the square indentation. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation as

$$HV = \frac{2F\sin\frac{136°}{2}}{d^2}$$

. Vicker's hardness testing machine and a specimen for hardness testing are shown in Figure 6(a) and Figure 6(b).

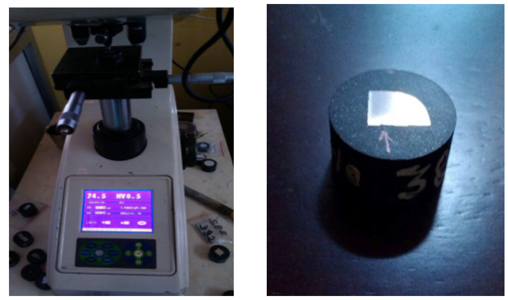


Figure 6(a). Vicker's Hardness Testing Machine. **Figure 6(b).** Specimen for Testing the Hardness.

The hardness values are taken at four different places and average hardness of the Al-Nano TiO_2 composite is calculated. The Vicker's hardness (HV) values are plotted in graph for various weight percentage of nanoTiO_2 reinforcement and are indicated in Figure 7. and Figure 8.

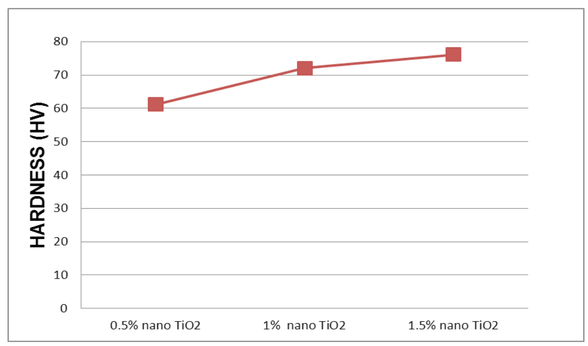


Figure 7. Vicker's Hardness values of Al- TiO_2 composites.

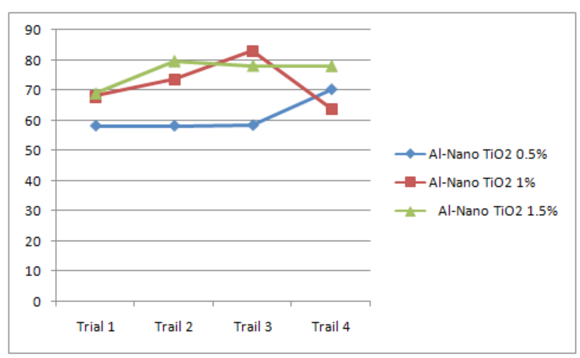


Figure 8. Mean hardness.

The addition of nano TiO_2 increases the hardness of the composite material than those for pure aluminium (33HV)[5,9–14]. The improved hardness by increasing the weight percentage of nano TiO_2 particles mainly results from the presence of extremely harder nano- TiO_2 particles in Al6061 matrix material.

3.4 Tensile and Compressive Properties

Typical stress strain curves for the aluminium-TiO_2 nano composite are shown in Figure 9. It can be understood that the enduringness will increase with increasing weight proportion of nano TiO_2 up to a quarter and starts decreasing anon, which indicates the impact of nano TiO_2 on the sweetening of mechanical properties of the composite.

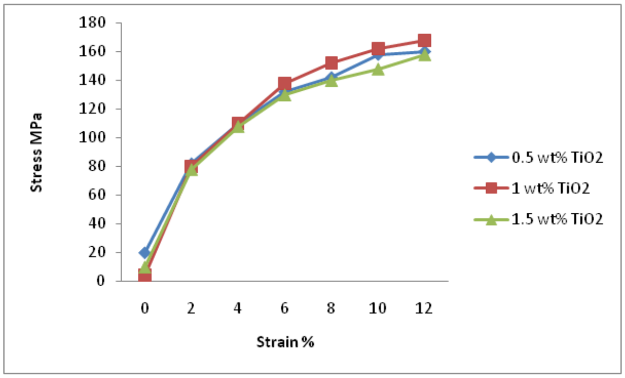


Figure 9. Stress-strain curves of Al-nanoTiO_2 composites.

The ultimate compressive strength for the composite is increased with an increase in the content of nano TiO_2 particles up to 1% and is decreased for 1.5% and is depicted in Figure 10. and it is higher than that for pure Al(130MPa)[5].

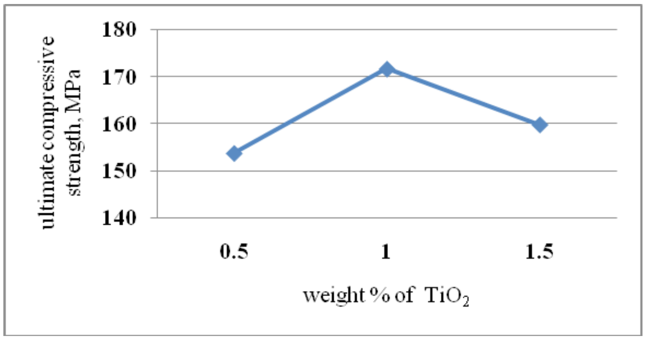


Figure 10. Ultimate compressive strength of Al- nanoTiO_2 composites.

4. Conclusion

The stir casting liquid metallurgy technique is found to be appropriate to fabricate the aluminium-nano-TiO_2 metal matrix composites. Micro hardness of the composites magnified for increasing weight share of nano TiO_2 bit by bit. Aluminium with 1 weight weight percentage nano TiO_2 composite shows the utmost compressive and lastingness. The micro hardness, tensile and compressive tests have revealed increased mechanical properties of Al - nano TiO_2 composites due to the impact of nano reinforcement. Wear rate and co-efficient of friction of the aluminium - nano TiO_2 composites are reduced up to at least one weight share of nano TiO_2 and are magnified for higher percentages of nano TiO_2. Further nanoTiO_2 contributed considerably in rising the wear resistance of Al- nano TiO_2 metal matrix composites. The non-contact surface roughness for the composites is reduced for increased addition of nano TiO_2. It can be finished that Aluminium 6061- nano TiO_2 metal matrix composites exhibits superior wear and mechanical properties.

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