Influence of TiO_2 on Mechanical and Wear Characteristics of Aluminum Matrix Composites Synthesized by Stir Casting Route

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Abstract— *Composite materials have a wide range of new potential applications in various technological areas such as aerospace, automobile, energy, medicine and chemical industry. In this work, 0, 3, 6 and 9 weight percentages of TiO_2 particles were incorporated into the 6063 aluminum alloy by using stir casting process. A uniform distribution of reinforcement was observed by SEM of the composites. Characterization of mechanical properties revealed that the presence of particles significantly increased tensile strength and hardness of the composite by more effectively promoting the particle hardening mechanisms of micron size particles. The highest tensile stress was obtained by 9 wt. % of TiO_2 particles. It was revealed that the presence of TiO_2 reinforcement led to significant improvement in yield strength and ultimate tensile stress while the ductility of the AA6063 matrix is retained. The wear rate increase with increase in load and dependent upon TiO_2 loading in the AA6063. With the composites tested AA6063- TiO_2 composites containing 9 wt. % TiO_2 exhibited superior wear resistance.*

Keywords: *AA6063, SEM, Titanium oxide, Wear.*

I. INTRODUCTION

In recent years, metal matrix composites are widely used huge functional and structural applications due to its unique properties such as high strength with lightweight. AA6063 is also known as architectural and decorative alloy; because of its easily extrudable property, distinctly superior finishing quality and strength. It is widely used for boat, ship building, automotive and aerospace applications due to its superior properties [1-3]. The reinforcement particles to interaction of particles with dislocations become of major importance and results in an amazing development of mechanical properties [4]. The different kinds of matrix metals have been together with several types of metric phases. Ceramic compounds such as TiO_2, TiC, SiC, Al_2O_3 intermetallic materials and carbon allotropes were used to reinforce Mg, Al, Cu and other metals and alloys. TiO_2 reinforcement has a capability to generate a material with a high thermal conductivity, excellent mechanical properties and attractive damping behavior at higher temperatures [5]. Stir casting is a liquid state method of composites fabrication in which a dispersed phase is mixed with molten matrix metal by using mechanical stirring. When compared to other fabrication techniques, the cost of stir casting process is much lower than other manufacturing techniques of MMC's. Stir casting is fitting for manufacturing composites with up to 30% volume fractions of reinforcement. The mechanical property results of composites led in to improvement of wear rate, yield strength, ultimate tensile strength, compressive strength and hardness. The fabrication process such as compo casting and the size of the reinforcement particles were the effective factors influencing on the mechanical properties [6]. The improvements in wear resistance of Al alloy-SiC particles reinforced composite is a strong function of reinforcement content and its size [7, 9]. The occurrence of SiC makes the composites hard to be machined due to its brittle property. Baradeswaran et al. [8] examined the wear behaviour of B_4C and graphite reinforced AA6061 and AA7075 based composites produced by liquid casting method and concluded that the higher wear resistance enhanced by AA7075/B_4C/graphite composite than the AA6061 based composite. Adding up of metal oxides like TiO_2 shifts the brittleness of SiC and widens its engineering applications. Use of TiO_2 as reinforcement in aluminium alloy has established modest attention even though it posses high hardness and modulus in the midst of superior corrosion resistance [10-11]. Vital enrichment in wear resistance and hardness characteristics were achieved with Al6061 alloy with TiO_2 reinforcement. Hardness, density and wear rate was improved with TiC and TiO_2 reinforcements with Al alloy [12, 13]. Jojith et al. [14] compared the tribological behaviour of LM13/TiO_2/MoS_2 hybrid composite and unreinforced alloy. It observed that the wear rate in hybrid composite is reduced due to the presence of TiO_2 and MoS_2 particles in the matrix, which improves the hardness and self lubricating properties.

Kumar et al. [15] renowned that abrasive wear resistance enhanced by the addition of TiB_2 particle in the Al-4Cu alloy and it increases as the TiB_2 content in the composites increases. Severe plastic deformation and adhesive wear were found on the worn surfaces of the TiB_2/Al composites. Ambigai et al. [16] fabricated Al-Si_3N_4 nanocomposites and Al-Gr-Si_3N_4 hybrid composite and the effect of reinforcement, load and sliding distance on wear rate and coefficient of friction were explored under dry sliding wear conditions.

In this paper, the AA6063-TiO_2 nano composites with various amounts of titanium oxide mixed by using stir casting with ultrasonic vibrator technique. The obtained composites were analyzed for micro structural and mechanical properties.

II. Experimental work

AA6063-TiO_2 composites were prepared by stir casting technique, aluminum alloy 6063 was used as a matrix and the chemical composition is shown in Table 1. Titanium dioxide particles (Figure 1) were used as reinforcement and the properties are shown in Table 2. The AA6063 pieces were heated in a crucible, the TiO_2 reinforced particles and Mg is preheated ramblingly for 30 minuets by improving the wettability. AA6063 were mixed with the ceramic particles to prepare composites with about (0, 3, 6 and 9) wt. % reinforcement by using stir casting route is shown in Figure 2. The AA6063 was melted in crucible and the preheated TiO_2 particles are gently added at the temperature of 750ºC and a constant dynamic stirring was done for 5 minutes at a speed of 700 rpm. The stirring was used to make sure the homogeneity of the molten metals. The molten mixture was poured into cast iron mold as a rod form. Microstructures of the composites were studied using scanning electron microscopy (SEM). The mechanical properties such as tensile strength, microhardness and impact strength and wear characteristics are evaluated by Universal testing machine, Vickers hardness tester, Charpy V-notch test and Pin-on-disc machine respectively as per ASTM standards.

Table-1: Chemical composition of AA6063

Material	Elements (weight percentage)						
	Si	Mg	Fe	Cr	Mn	Cu	Al
AA6063	0.44	0.56	0.46	0.03	0.03	0.02	Bal

Table-2: Properties of TiO_2 powder

S.No	Properties	Values
1	Density	3970 kg/m^3
2	Melting point	1843°C
3	Thermal Conductivity	11.8W/m.K

Fig-1: Titanium oxide powders

Fig-2: Experimental setup of stir casting process

III. Results and Discussion

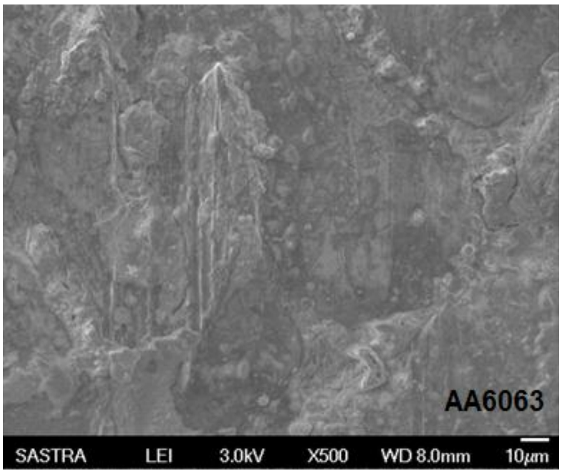

Fig-3: SEM images of casted AA6063 composites

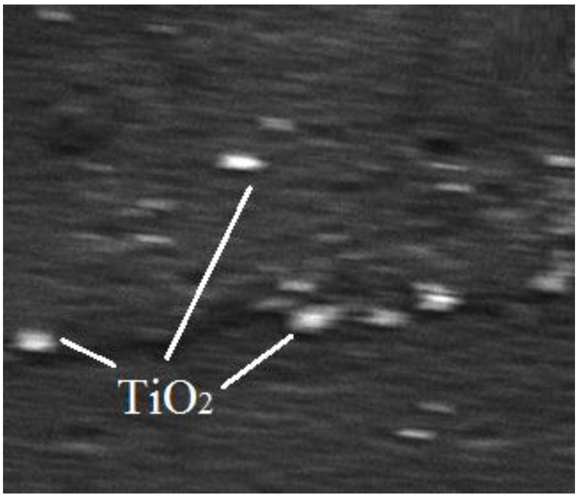

Fig-4: SEM images of AA6063-TiO_2 composites

Figure 6 shows the stress-strain curves of the AA6063-TiO_2 composites. From these stress-strain curves the tensile properties are drawn such as ultimate tensile strength, yield strength and percentage of elongation. The ultimate tensile strength of composites is enriching with increased wt. % of TiO_2 in AA6063 matrix. The bonding between the TiO_2 and AA6063 is established solid enough; the ultimate tensile strength of 9 wt. % TiO_2 composite can be greater than unreinforced AA6063 composites.

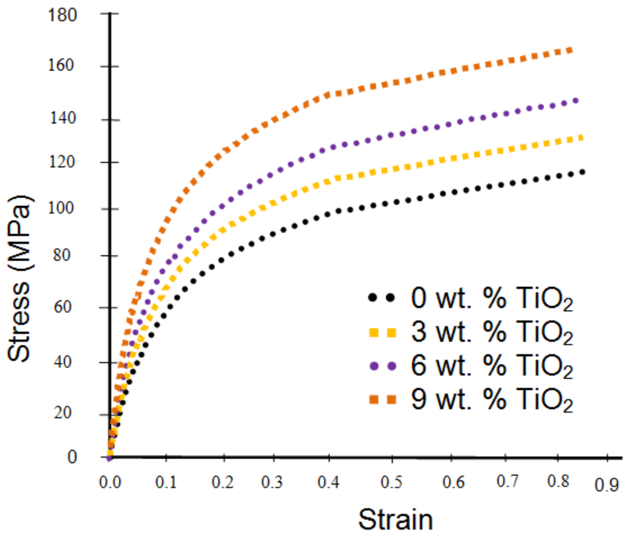

Chart-1: Stress-strain curve of AA6063-TiO_2 composites

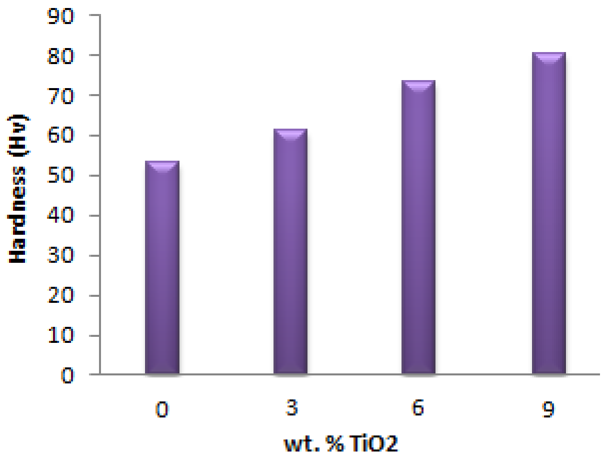

Chart-2: Hardness of AA6063-TiO_2 composites

The effect of weight percentage of TiO_2 on hardness of AA6063 matrix composites are shown in Figure 7. The increase in hardness is attributed to the incorporation of hard TiO_2 into a soft, ductile AA6063 matrix enhances the hardness of matrix materials. The maximum hardness is achieved at 9 wt. % TiO_2 composite. The TiO_2 particles like most hard and brittle ceramic particles have a higher tendency to undergo rapid crack propagation. The effects of weight percentage of TiO_2 on impact strength of AA6063 composites are shown in Figure 8. The increase in impact strength was observed until 9 wt. % of TiO_2. The reason for the increase in impact strength could be the proper interfacial bonding between AA6063 matrix and TiO_2 particles in the composites. The maximum impact strength of 61 MPa for 9 wt. % TiO_2 composite was achieved. TiO_2 particles act as a barrier and restrict the composite from local plastic deformation.

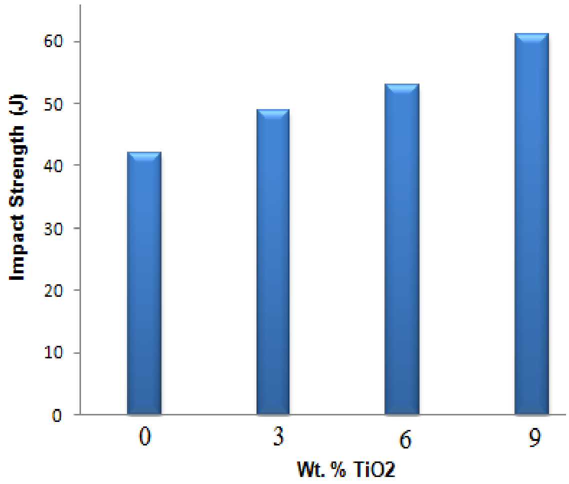

Chart-3: Impact strength of AA6063-TiO_2 composites

The result of wear rate of the AA6063 composites with different weight percentages of TiO_2 particles is shown in Figure 9. The wear rate decreases with increase in the weight percentage of reinforcing TiO_2 as compared to unreinforced AA6063 composites, the reason is lubricating properties and hardened nature of reinforced particles. The initial increase in wear rate in the case of unreinforced AA6063, particularly during the as-cast condition is due to inhomogeneity in as-cast structure exhibited by the alloy of AA6063. The decrease in wear rate can be attributed to an increase in fraction of TiO_2 particles which possessed high hardness with better interfacial bonding between the TiO_2 particles and AA6063 matrix formed during stir casting process. Lowest wear rate is attained for 9 wt. % of TiO_2 composites at all level loads. Wear rate goes on increasing with increase in loads. With increase in sliding speed wear rate goes on decreasing. Over sliding speed is directly proportional to test time. Wear rate goes on decreasing with increase in test time of samples and disk. Similarly the increase of sliding distance reduces the coefficient of friction. The harder and thermally stable phase TiO_2 in greater amount reduces the coefficient of friction. The TiO_2 was able to enhance wear resistance of the composites at a temperature higher than the room temperature.

The high sliding velocity may result in strong formation of oxide layer of the materials due to high temperature on the worn surface and it can act as an effective insulation layer between pin and the disc, which leads to major improvement in wear resistance.

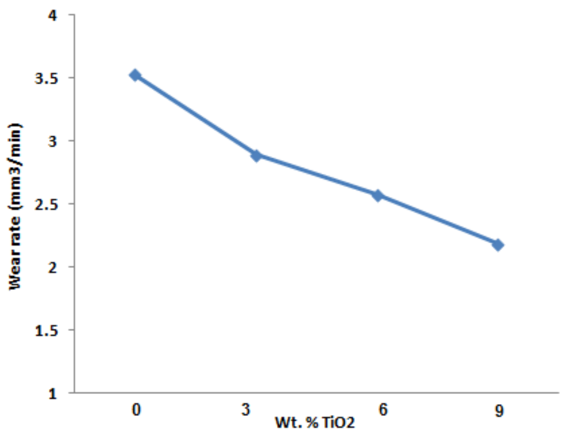

Chart-4: wear rate of AA6063-TiO_2 composites

IV. CONCLUSIONS

In this research work, the Influence of TiO_2 on mechanical and wear characteristics of aluminum matrix composites synthesized by stir casting route. The following conclusions are drawn:

- The defect free composites samples were achieved by the optimized stir casting process parameters.
- The uniform distribution of TiO_2 particles in the AA6063 matrix materials were conformed by the scanning electron microscopy.
- The higher mechanical properties like tensile, hardness and toughness were observed for the AA6063 - TiO_2 composites compared with unreinforced AA6063 composites.
- The highest mechanical properties were obtained for AA6063 -9 wt. % TiO_2 composites. TiO_2 particles act as a barrier and restrict the composite from local plastic deformation.
- The wear rate decreases with increase in the weight percentage of reinforcing TiO_2 as compared to unreinforced AA6063 composites, the reason is lubricating properties and hardened nature of reinforced particles.
- The coefficient of friction decreases with increase in weight percentage of TiO_2 reinforcement and load.

V. REFERENCES

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