Hardness and Wear properties of Aluminium based hybrid metal matrix composite

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ABSTRACT

The main objective of our study is to test and analyze the mechanical properties of Hybrid composite material. The above mentioned composite material are made up of aluminum as matrix which is reinforced equally with SiC and TiO_2 in various compositions (2.5, 5, 7.5 vol. %) The prepared composite material is subjected to mechanical and tribological property properties such as Hardness and wear test and the values are compared with LM25 aluminium alloy. The results show that composite material with the addition of SiC and TiO_2 as reinforcement leads to increase in the hardness, and wear resistant than aluminium. The hybrid composite material is also subjected to microstructure analysis for the particle distribution it shows the reinforcement material are uniformly distributed.

Key Words: Stir-casting, Silicon carbide, Hardness, Titanium dioxide, Wear rate

1. Introduction

A material composite can be defined as a material consisting of two or more physically and chemically distinct parts, suitably arranged, having different properties respect to those of each constituent parts. This is a very large family of materials whose purpose is to obtain certain property resulting by the combination of the two constituents (matrix and reinforcement), in order to to obtain the mechanical characteristics (and sometimes thermal) higher than that it is possible to have with their corresponding matrices. For this reason, about the wide range of new developed materials, composites are certainly those able to comply better the needs of most technologically advanced industries. Essam R.I [1] concluded that by adding 12 volume% of α – alumina particles with aluminum leads to improve brinell hardness number (BHN) by 89% and compression strength by 54% comparing with base aluminum material. By adding 10 volume% of silicon carbide particles with aluminum leads to increase the hardness and impact strength. Hardness is increased by 1.84 times and material toughness increased by 2.1 times higher than the unreinforced aluminum [2]. The search for cheaper, easily available reinforcement has led to the wider use of silicon carbide and alumina particles. Therefore, the application of particle reinforced MMC's are now dominating the MMC market [3].

In the stir casting method, the reinforcing particles is introduced into the melt and stirred thoroughly to ensure their proper mixing with the matrix alloy. The properties of particle-reinforced metal matrix composites produced by stir cast method has influenced by various parameters such as type, size & weight fraction of reinforcement particles and its distribution in cast matrix metal. It also depends on their solidification behavior during casting. The rate of solidification has a significant effect on the microstructure of cast composites, which in turn affects their mechanical properties. From the moment of crystallization and solidification commencement, the crystalline phase begins to grow. Its growth proceeds in a direction opposite to the particles' movement. Thus, apart from the geometric factor, i.e. the type, volume fraction and size of reinforcing particles, it is the crystallization rate and the casting's solidification time that determine the structure obtained and particles' distribution in the matrix [4].

Temperature rise for hybrid composite is more than that of temperature rise for binary composite but it is significantly lower than iron-based composites. Hybrid composites with lower wear resistance have better tribological characteristics than iron-based composites [5].

The goal of this work is to prepare hybrid metal matrix composite with SiC and TiO_2 of varying volume fraction of reinforcement (5,10,15%) and subject it for the Hardness test using Vickers hardness tester and wear testing. The sliding wear behavior of the composite is found to be a function of many factors such as volume fraction and particle size of reinforcement, hardness and strength of matrix alloy, applied load, environmental temperature etc. The investigation of sliding wear properties of aluminium MMCs with reinforcement such as SiC, Al_2O_3, TiC, TiB_2 and graphite has been carried out by the researchers [6-10]

2. Manufacturing of hybrid metal matrix composite (MMCs)

The LM25 aluminium alloy is used as the Matrix material. Stir- casting is chosen in preparing composite samples. This method could distribute silicon carbide and Titanium dioxide particles homogenously in the aluminum microstructure by forming vortex in molten metallic. It could pull silicon carbide and Titanium dioxide particles through molten metallic and distributed them homogenously. Stir casting improve mechanical and physical properties of the aluminum matrix. The chemical composition of LM25 alloy is shown in table 1.

Elements	Cu	Si	Mg	Mn	Fe	Ti	Ni	Zn	Sn	Al
Percentage	0.17	6.81	0.51	0.03	0.29	0.103	0.006	0.06	<0.001	Balance

Table 1. Nominal chemical composition of LM25-Al alloy

Fig 1. Stir casting setup

Matrix material LM25 aluminium is cut into small pieces. The matrix material say one kg is heated in the electric induction furnace the temperature of the mould is raised to above the melting point of aluminium to 800°c to 900°c The molten metal of aluminium alloy is stirred using the mechanical stirrer through motor the depth of the stirrer is kept as two thirds for the for motion of vortex in the molten metal. The reinforcement particle SiC and TiO_2 is preheated for an hour to a temperature of 550°c for the moisture to evaporate. Then the reinforcement is added in to the vortex of molten metal slowly by stirring is done continuously, The three different volume fraction of reinforcement (2.5, 5, 7.5 %) SiC and TiO_2 is done to get the three different composite.

To ensure the homogeneity of the added silicon carbide particles through molten aluminum, electrical mixer was inserted in the melt. Molten aluminum was stirred at 400 rpm to get suitable vortex. Later silicon carbide and Titanium-di-oxide particles were added to molten metal. This process was followed to modify reinforcement particles distribution through the molten aluminum.

Due to the vortex effect, silicon carbide and Titanium-di-oxide particles were pulled inside the molten metal and uniformly distributed. Molten aluminum was stirred for five minutes until the molten aluminum becomes slurry. Later molten aluminum was poured into suitable stainless steel mould, which is preheated at 250°C to prevent sudden cooling for molten aluminium. Thus the hybrid composite material is manufactured by stir casting.

3. Experimentation

Hardness

The Vickers hardness test results of cast LM25 aluminium alloy and their composites containing SiC & TiO_2 were presented in the form of graph showing the relationship between the Vickers hardness values and the particle volume fraction. From the hardness test results Fig.2 it can be observed that the hardness of the composite is marginally greater than that of the base matrix LM25. The composites containing higher volume fraction of reinforcement has higher hardness value of 305 VHN when compared to the base matrix, 118 VHN.

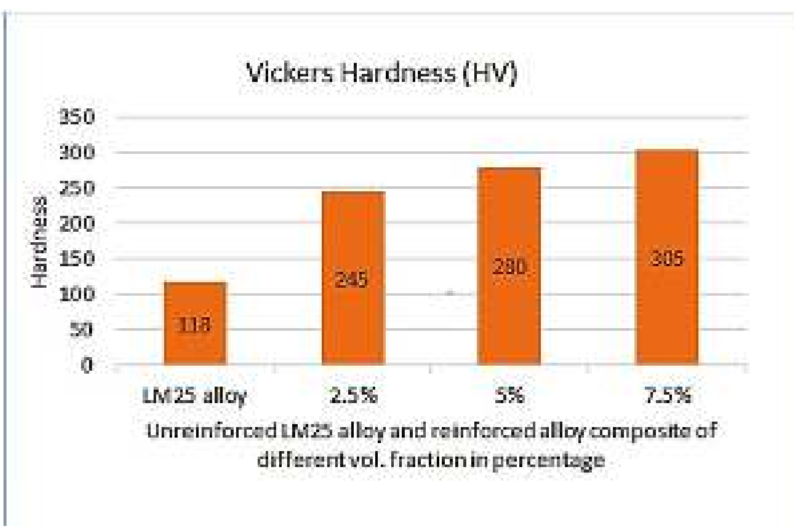

Fig 2. Comparison of hardness between LM25 alloy and hybrid composite

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The graph shows the effect of silicon carbide and titanium dioxide particles on aluminum hardness, the result show that, hardness increases with increasing reinforcement of volume fractions. It reaches maximum hardness valve 312 VHN at 7.5 vol% silicon carbide and titanium dioxide particles. This is due to the high hardness values of reinforced particles in comparison with aluminum hardness and to the good bonding between the reinforcement particles and matrix phases.

Wear test

The wear test are conducted at room temperature in a pin on disc wear testing machine (Wear and Friction monitor TR-201). The pins are loaded against the disc by a dead weight loading system. The pin specimen is flat ended with 8mm diameter and 20mm length. The disc test piece is 100mm in diameter and 10mm in thickness. They slide on the disc by a diameter of 50mm. The material of the disc is hardened steel of HV698.Wear test on composite specimen (LM25+SiC & TiO_2) and unreinforced LM25 alloy were carried out under dry sliding condition at three different applied loads of 29.43N (3Kgf), 39.24N (4Kgf) and 49.05N (5Kgf) for a total sliding distance 628m at a constant sliding speed of 1.04m/s. During the test the relative humidity and temperature of the surrounding atmosphere is about 50% and 25°C respectively. The test duration is 10 minutes at a constant disc speed of 400 rpm for all the test.

The vertical height (displacement) of the specimen is continuously measured using linear variable differential transformer (LVDT) of accuracy 1μm during the wear test and the height loss is taken as wear of the specimen. The photographic view of the pin on disk wear tester used in this investigation is shown in Fig.3.

Fig 3. Photographic view of pin on disk wear testing machine

4. Results and discussion

Effect of load and sliding distance on wear rate

The results indicated that the wear rate of the unreinforced and reinforced composite specimen increases with increasing the sliding distance and load. From Fig 4, it has been asserted that the unreinforced alloy specimen increases more rapidly with applied load compared with the composite specimen. The test exhibit two regions which is ‘running in’ and ‘steady state’ periods. During running-in period the wear rate increased very rapidly with increasing sliding distance. During steady state period, the wear progressed at a slower rate and linearly with increasing sliding distance. The higher wear rate at the initial stage is due to the adhesive nature of the sample to the sliding disc [11-12].

The results indicated that the particulate reinforcement SiC and TiO_2 has a marked effect on the wear rate. The wear rate of the composite specimen decreases with the increasing volume percentage of particulate reinforcement. As expected, the wear rate of the composite specimen with a fixed volume percentage of reinforcement increases with increasing applied load At constant applied load the composite specimen shows lower wear rate than unreinforced alloy.

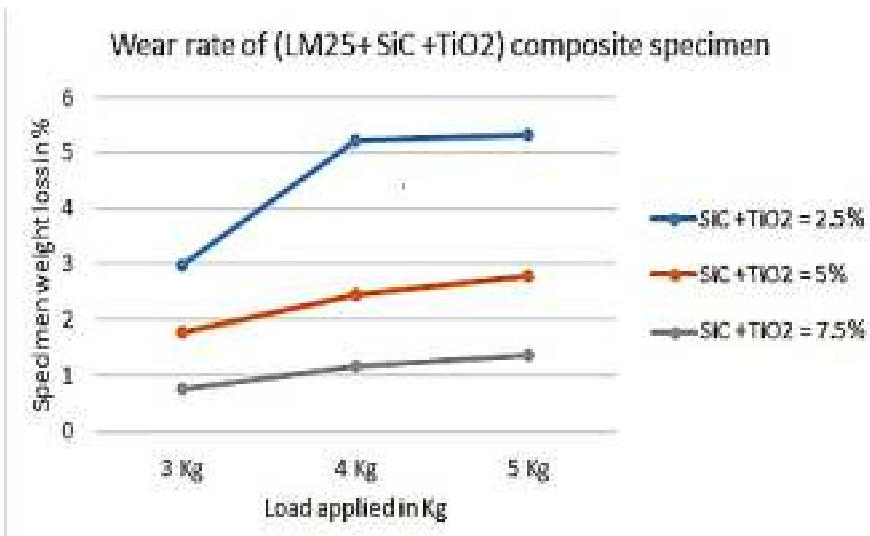

Fig 4. Weight loss of LM25 composite material in pin on disk wear tester

The above Fig 4. reveals that as the percentage of reinforcement SiC and TiO_2 increases there is reduction in the percentage of weight loss of the composite material in pin on disk wear tester. From Fig 4. at 2.5% SiC and TiO_2 reinforcement of LM25 alloy the wear is severe and at 7.5% reinforcement it is mild. The experimentation also says as the applied load increases gradually there is increases in the weight loss due to wear of the composite material while sliding with the wear disc .The increase in the reinforcement of

SiC and TiO_2 has a marked effect on the wear resistance property .The wear resistance increases with the increases in the volume percentage of the reinforcement.

5. Micro structural studies

The optical micrographs of unreinforced LM25 alloy and its composite with 2.5%, 5% and 7.5% volume fraction of reinforcement SiC and TiO_2 is shown in Fig. 5 (a) –(d). The micro structural analysis of the specimen indicated that that the SiC and TiO_2 particle are uniformly distributed in the matrix. The presence of porosity is seen around the SiC and TiO_2 particles. It is observed that the porosity is more around the TiO_2 particles than the SiC particles. The porosity of the specimen increases with the increasing volume fraction of the particulate reinforcement

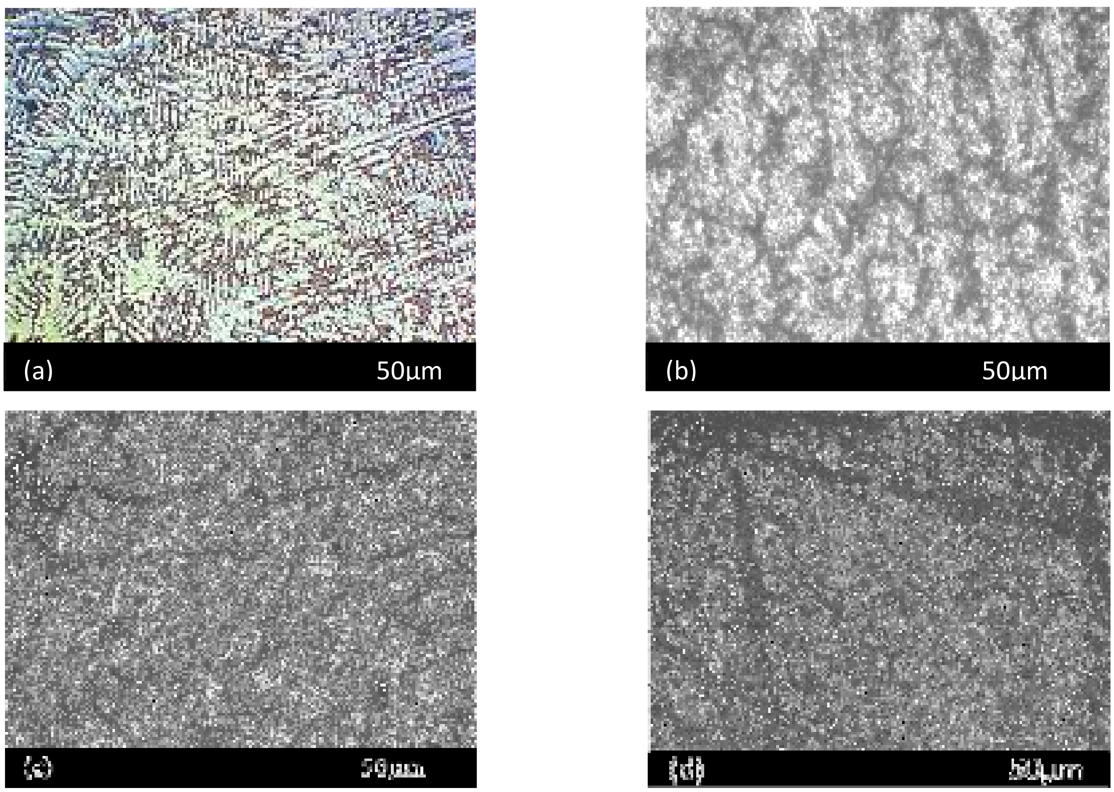

Fig 5. Optical micrograph of (a) unreinforced alloy (b) LM25+ 2.5% reinforcement (c) LM25 + 5% reinforcement and (d) LM25+7.5% reinforcement

Conclusion

The hybrid metal matrix composite with SiC and TiO_2 as reinforcement subjected to mechanical testing exhibits the enhanced mechanical properties as concluded below:

1. The LM25 alloy and their composites have been successfully developed through the stir casting based liquid processing route with fairly uniform dispersion of particle distribution.
2. The hardness of LM25+ SiC and TiO_2 composite increases as the addition of reinforcement increases and the increment in hardness attributes to particles dispersion in soft aluminium alloy matrix.
3. The addition of SiC and TiO2 particulate significantly improves the wear resistance of LM25 alloy, when compared with that of unreinforced matrix.
4. The improvement in mechanical and tribological property of lightweight materials finds wider application in enhancing the efficiency of the system and machineries.
5. The wear resistance obtained with the influence of reinforcement SiC and TiO2 can be subjected to further studies in finding the unique properties of individual reinforcement in future research work

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