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Influence and Wear Characteristics of TiC Particle in Al6061 Metal Matrix Composites

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Abstract

Metal matrix composites have excellent wear resistance and widely used to replace automobile and aircraft industry materials. The aluminium based metal matrix composites are substitute the materials for fabrication of cyclinder head, break rotor, cyclinder lines .of all the commercial aluminium alloy 6061 popular choice for fabrication of metal matrix composites. The investigation revels with the wear behavior of Al6061 metal matrix composite reinforced TiC .The composite materials fabricated by stir casting method and wear test done by pin on disc apparatus .the present work deals with the investigation of wear resistance measured with in terms of weight loss of aluminium matrix composites.

Keywords: Hybrid composites, DOE, stir casting, pin on disc apparatus, wear

INTRODUCTION

A Metal matrix composite is an engineered combination of two or more materials (one of which is a metal) in which tailored properties are achieved by systematic combination of different constituents. In MMCs, ceramics or metals in form of fibres, whiskers or particles used to reinforce in a metal matrix. The composites are mainly used in aerospace, automobiles, marine engineering and turbine-compressor engineering applications for light weight. Aluminium and its alloys play an important role in the production of MMC.AMC materials have greater advantages in a wide number of specific fields due to their high specific strength, stiffness, wear resistance and dimensional stability. Fabrication methods are important part of the design process for all structural materials including AMCs. Stir casting technique is the conventional and economical way to fabricate the metal matrix composites. In particulate reinforced MMC, reinforcement is added to the matrix of the bulk material to increase its stiffness and strength. Furthermore, the use of discontinuous reinforcement minimizes the problems associated with the fabrication of continuous reinforced MMC such as fibre damage, micro structural heterogeneity, fibre mismatch and interfacial reactions. It was reported that several key factors such as type, size and volume fraction of particles as well as the interfacial particle/matrix bonding had a pronounced influence on the wear behaviour of the reinforced composite. Only a few works on the wear characterisation of Al reinforced with TiC composite have been reported so far. S.Gopalakrishnan, N.Murugan researched the Production and wear characterization of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method. In this study Al–TiCp castings with different volume fraction of TiC were produced in an argon atmosphere by an enhanced stir casting method. It shows that the specific strength of the composite has increased with higher % of TiC addition and reveals the improved specific strength as well as wear resistance of Aluminium matrix composites [1]. Falcron-Franco L reported the Wear performance of TiC as reinforcement of a magnesium alloy composite. It was reported that several key factors such as type, size and volume fraction of particles as well as the interfacial particle/matrix bonding had a pronounced influence on the wear behavior of the reinforced composite [2]. Rajnesh Tyagi have investigated the Synthesis and tribological characterization of Al–TiCp composite produced by in situ process revealed that the wear rate decreased linearly as the volume fraction of TiC increased from 7% to 18% [3].. A.G.Kostornov investigated the prospects of improving the tribological characteristics of titanium composites without lubrication at different sliding velocities. It shows that the titanium-based composites are promising as antifriction materials at an increased sliding velocity [4].

Qunji Xue have investigated the tribological properties of SiC whisker and molybdenum particle reinforced aluminum matrix composites under lubrication and revealed that the composites exhibited good friction- and wear-resistance properties. It shows that with increasing load, the wear rate increases quickly and the wear mechanism is plowing with delamination [5]. Basavarajappaet al.'s investigation on Al 2219-SiC and Al2219-SiC- Graphite hybrid composites showed that the sliding distance, load, as well as sliding speed parameters were significant factors for wear by using Taguchi and ANOVA techniques [6]. S. Dharmalingam investigates the optimization of dry sliding performances on the aluminum hybrid metal matrix composites using gray relational analysis in the Taguchi method Using a pin-on-disk apparatus, the volume loss and frictional force are measured and the results used to evaluate the dry sliding performances are specific wear rate and coefficient of friction[7]. Aravind Vadiraj investigated the friction and wear behaviour of MoS2, boric acid, graphite and TiO2 at four different sliding speeds (1.0, 1.5, 2.0, 2.5m/s) and compared with the dry sliding condition. The results show the friction coefficient reduces with increase in sliding speeds for all the conditions [8].

EXPERIMENTALDETAILS

Selection of Matrix Material

Aluminium, the second most abundant metallic element on the earth, became an economic competitor in engineering applications recently. The metal matrix selected for present investigation was based on Al-Cu- Mg alloy system, designated by the American Aluminium Association as Al 6061. The chemical composition of the matrix material is as shown the Table 1.

Table 1. Chemical composition of Al 6061 alloy

Element	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	Al
wt. %	0.003	0.24	0.16	0.89	0.48	0.63	0.014	0.007	97.57

This matrix was chosen since it provides excellent combination of strength and damage tolerance at elevated and cryogenic temperatures. It is an age harden able alloy suitable for high temperature and high strength applications like structural components and high strength weldments. It also has a high heat dissipation capacity due to its high thermal conductivity (Davis 1993)

Selection of Reinforcement Materials

TiC particles are the most commonly used reinforcement materials in the discontinuously reinforced metal-matrix composite system. The benefits of using TiC particles as reinforcement are improved stiffness, strength, thermal conductivity, wear resistance, fatigue resistance, and reduced thermal expansion. The chemical composition of TiC is shown in Table 2. Additionally, TiC reinforcements are typically low-cost and have a relatively low density. Particle size and shape are important factors in determining materials properties. Fatigue strength is greatly improved with the use of fine particles. The TiC particles, which were used to fabricate the composite, had an average particle size of 23 μm and average density of 4.93 g / cm3. It is the second hardest material after diamond with a Mohr's hardness of 9.5. The melting point of the TiC is 3160 0C.

Composite Preparation

In order to achieve high level of mechanical properties in the composite, a good interfacial bonding (wetting) between the dispersed phase and the liquid matrix has to be obtained. Stir-casting technique is one such simplest and cost effective method to fabricate metal matrix composites which has been adopted by many researchers. This method is most economical to fabricate composites with discontinuous fibres and particulates and was used in this work to obtain the as cast specimens. In this process, matrix alloy (Al 6061) was first superheated above its melting temperature and then temperature is lowered gradually below the liquidus temperature to keep the matrix alloy in the semisolid state. At this temperature, the preheated TiC particles were introduced into the slurry and mixed. The composite slurry temperature was increased to fully liquid state and automatic stirring was continued to about five minutes at an average stirring speed of 300-350 rpm under protected organ gas.. This blended mixture is introduced into the molten liquid slurry and stirring is continued. The molten metal was then poured into a permanent cast iron mould of diameter 26mm and length 300mm. The die was released after 6 hours and the cast specimens were taken out. The pin-on-disc test apparatus shown in Fig. 1 is used to investigate the dry sliding wear characteristics of the composite as per the ASTM G99-95 standard. During the test, the pin is pressed against the counter face EN32 steel disc with a hardness of 65 HRC. After traversing a fixed D, the specimen is removed, cleaned with acetone, dried, and weighed to determine the mass loss due to wear.

Wear Test

Composite specimens were subjected to wear test under dry sliding condition using a pin- on-disc type apparatus (Figure 3) at room temperature, with a relative humidity of 30% and a disc velocity of 2 m/s. Wear tests were conducted on 10 mm diameter and 25 mm long cylindrical specimens against a rotating EN-32 steel disc (counter face) having a hardness of 63 HRc. The tests were conducted as per the ASTM G99-05 standards. The specimen's ends were polished with 1200 grit SiC emery paper and cleaned with acetone before every run. The initial weight of the specimen was measured before each experiment using a single pan electronic weighing machine with an accuracy of 0.0001g. The specimen was fixed on the specimen holder. The load was applied to the specimen and the arm of the apparatus was balanced by means of a counted weight. A fixed track diameter of 120mm was used in all tests, with a maximum sliding distance of 2000m. The duration of the experiment was controlled by a built in timer mechanism. After each experiment the specimen was removed, cleaned with acetone and weighed to determine the weight loss. Each test was repeated three times and the results were averaged.

Figure 1. Pin on Disc Apparatus

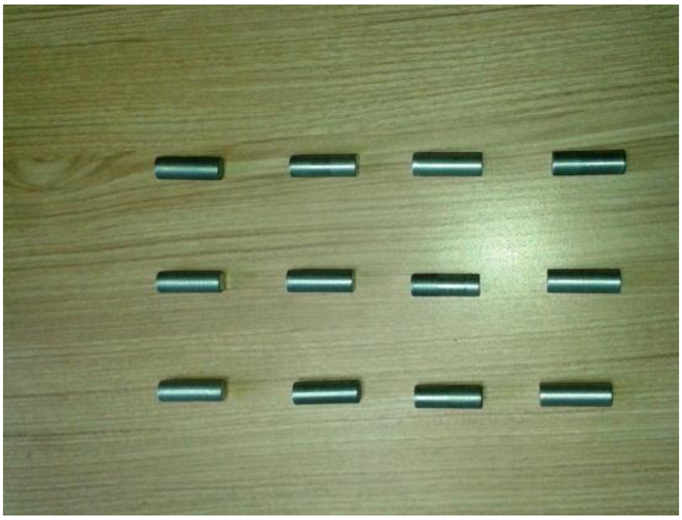

Figure 2. Specimens prepared for wear test

Design of Experiment

Design of experiments (DOE) is a formal structured technique for studying any situation that involves a response that varies as a function of one or more independent variables. In the present investigation the response (weight loss) varies as a function of weight percentage of TiC, applied load and sliding distance, Velocity .The factors and their level used for the present work are listed in Table 2.

parameters	-2	-1	0	1	2
% of TiC	1	2	3	4	5
Sliding velocity	1	2	3	4	5
Load	10	20	30	40	50
Distance	300	400	500	600	700

RESULTS AND DISCUSSION

Microstructure

Microstructural studies were carried out using JEOL model SEM. Micrographs of the wear surface of the Al 6061 hybrid composite specimens are shown in Figure 4 (a-d).After wear of the composite specimen, a non-uniform wear consisting of grooves, micro cutting and scratch marks that have been formed by the reinforcing materials were observed. This indicates that the wear of the composite is due to abrasion wear. Delamination is also observed on the wear surface of the composite which induces sub surface cracks that gradually grow and eventually shear to the surface, forming long thin wear sheets.

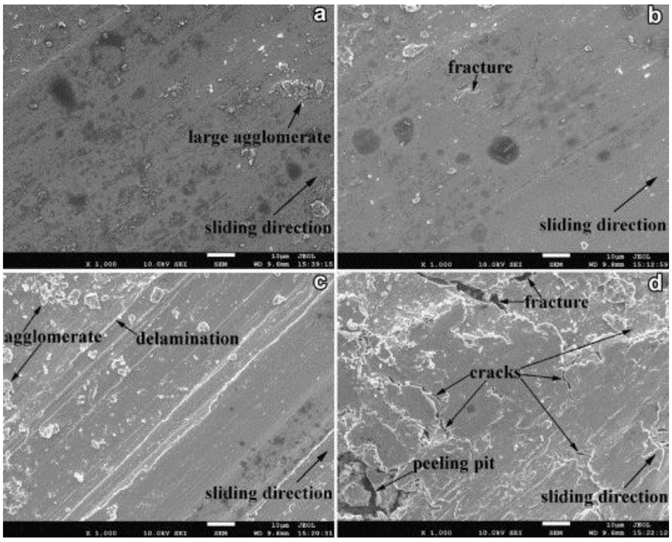

Figure 2. SEM image for Wear surface for Different loading and sliding distance

Hardness

The Rockwell hardness values of the composites with variation in the reinforcement content are shown in Table 6. Rockwell hardness measurements were made on a Rockwell hardness testing machine using an indentation load of 100Kgf and the corresponding value was read using the B scale. It is observed that the Rockwell hardness of Al 6061 composites increases significantly with decreasing content of the graphite particles.

A similar observation was observed by Mei- juan ZHANG etal.2010 who have stated that with increasing graphite content the hardness of composites decreases. Further, it can also be explained based on the dislocation densities.

Increased content of reinforcement in the matrix alloy leads to increased dislocation densities during solidification arising from a thermal mismatch of the matrix alloy and the reinforcement. The mismatch of the thermal expansion between matrix and reinforcement due to temperature change results in larger internal stresses and mismatches strain that affects the micro structure and mechanical properties of the composites. The matrix deforms plastically to accommodate the smaller volume expansion of the reinforcement particles. Enhancement in dislocation densities results in higher resistance to plastic deformation, leading to improved hardness (Prabhu swamy, Ramesh, and Chandrakumar,2007). The measurements show that an increase in graphite content for the same amount of TiC reduces hardness of the composite. An increase of about 52.4% is observed.

CONCLUSION

Aluminium hybrid composites containing TiC particles were fabricated using stir casting process. Wear tests were performed on specimens having smooth surface subjected to different applied load and sliding distance. The individual and interaction effect of the parameters, viz wt. % of TiC, wt. %, applied load and sliding distance were studied. Hardness measurements and microstructure studies were taken for both matrix alloy and composites. The conclusions derived from this study are as follows:

- The main and the interaction effects of significant combination of influencing factors within the range of investigation of Al alloy-TiC composites were studied by central composite rotatable design technique.
- Weight loss of composite decreases with rise in weight percentage of TiC particles and increases with rise in applied load and sliding distance.
- Rockwell hardness of aluminium composites increases significantly with decreasing content of TiC particles.
- Microstructure studies clearly reveal a non- uniform wear consisting of grooves, micro cutting and scratch marks indicating abrasion wear and delamination.

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