International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: http://dx.doi.org/10.7324/IJASRE.2018.32627

Volume 4, Issue 3
March - 2018

Evaluation of Wear characteristics of Aluminium 7075 based Metal Matrix Composite

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ABSTRACT

In this present investigation, efforts are made to study the Wear rate of as-cast Tungsten carbide particulates and Short E-glass fibers reinforced AA7075 Hybrid Composites. The vortex method of stir casting was employed, in which the reinforcements were introduced into the vortex created by the molten metal by means of the mechanical stirrer. Castings were machined to the ASTM standards on a highly sophisticated lathe. The degree of improvement of Wear characteristics of MMCs is strongly dependent on the kind of reinforcement. An improved Wear characteristic occurs on reinforced compared to Unreinforced MMCs alloys.

Key words: Tungsten carbide particulates, Short E-glass fibers, Al7075 alloy composite, Wear characteristics.

1 INTRODUCTION

Monolithic metals are not suitable many advanced engineering applications due to their poor properties in service conditions and at elevated temperatures. For advanced application, materials system must have tailor made properties like better mechanical, superior wear resistance and physical properties like low CTE, high thermal conductivity etc.[1-3] In this regard, a new class of material known as composites have been developed which can be defined as multiphase material made up of two or more physically and/chemically distinct phases known as matrix phase and reinforcement phase and possesses the characteristics of both the matrix and reinforcement phase [4-5]. The properties of composites can be designed and modified according to required applications by choosing appropriate matrix and reinforcement material that exhibit superior mechanical properties, excellent tribological property, good thermal and electrical conductivity coupled with low coefficient of thermal expansion when compared monolithic metals and alloys [6-7]. Compared to polymer and ceramic matrix composites, metal matrix composites (MMCs) have been the subject of significant research and development over the past three decades. They are gaining widespread popularity over the conventional metals / alloys in various high tech applications. This is because of its attractive and superior mechanical properties. Nowadays all fields of engineering utilize the metal matrix composite which are extremely efficient in terms of design and weight applications [8-9].

2. OBJECTIVES OF PRESENT WORK

This research is to determine Wear resistance of metal matrix composite - Al 7075 alloy reinforced with Tungsten carbide and E-glass. These reinforcements provide comparatively high Wear and corrosion resistance. The main objective of this project is to develop Al (7075)/ E-Glass & Tungsten carbide particulate metal matrix composites where the E-glass & Tungsten carbide are used as reinforcement material & Al 7075 is used as matrix material. Different weight percentages of Specimens are prepared by using liquid route metallurgy technique. Test specimens are prepared to evaluate Wear characteristics.

3. EXPERIMENTAL DETAILS

Following steps are carried out in our experimental work:
1. Material selection
2. Composite preparation
3. Testing

3.1 Material selection

The Al 7075 alloy (matrix material), WC 30-40 μm size particles (reinforcement) and 3mm long E-glass short fibers (reinforcement) were used for fabrication of MMCs. The chemical composition of Al7075 is given in the Table 1.

Table 1: Chemical Composition of Al 7075

Composition	Al	Zn	Fe	Mg	Mn	Cu	Si	Cr	Ti
% Composition	88.6	5.6	0.5	2.5	0.3	1.6	0.4	0.23	0.2

3.2 Composite preparation

The WC of 30-40 μm size and short E-Glass fibers were used as the reinforcement and the WC content in the composites was varied from 0% to 6% in steps of 2% by weight and E-glass short fibers are varied from 10% to 5% in steps of 2% by weight. Liquid metallurgy technique was used to prepare the composite materials in which the WC particles were introduced into the molten metal pool through a vortex created in the melt by the use of an alumina-coated stainless steel stirrer. Zirconium coated stirrer used to stir the molten metal. The stirrer was rotated at 550 rpm and the depth of immersion of the stirrer was about two-thirds the depth of the molten metal. The pre-heated (773^0K) WC particles and short E- Glass fibers were added into the vortex of the liquid melt. The resulting mixture was tilt poured into preheated permanent moulds.

3.3 Wear test

The specified specimen for friction and wear studies have been machined and examined in computerized pin on disc testing system as presented in Fig.3.1 Tests were conducted for specific loads and speeds with fixed track diameter of 135mm and fixed sliding distances of one km. The mating surface of the disc and pin turned into cleaned with the aid of using acetone. After measuring the diameter of the pin it is set up within the specimen holder. The specimen is weighed before mounting and therefore is taken into consideration as preliminary weight (W_1). Track radius R, the distance among the centers of the disc to the center of the pin is measured. After loading the specimen with preferred weights (steady load) the displacement in sensor is adjusted to zero. The motor is switched on causing the disc to revolve to the set Velocity and time. After set time is finished the specimen becomes removed from the holder and the load from the pan became eliminated. it's miles then weighed after thoroughly cleansing it in ultrasonic cleanser. This weight of the specimen is considered as the final weight (W_2). The distinction among the initial and the final weight gives the weight loss.

Fig 3.1: Photograph of pin on disc wear testing machine

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4. RESULTS AND DISCUSSION

4.1 Wear properties

4.1.1 Effect of hybrid reinforcements on wear rate

Fig. 4.1 shows the effect of hybrid reinforcements on the wear rate of AL7075 hybrid composites. The reduction in wear rate is almost 52% which elucidate imperative wear resistance by high weight percentage of Tungsten carbide and E glass fibre content. It can be noticed that AL7075-6%WC-5%E-GF hybrid composite has got highest hardness. As according to law of Archard's the wear loss of the material during wear test is inversely proportional to the hardness. So in present case as AL7075-6%WC-5%E-GF has got highest hardness the wear rate in this composite was also established low when evaluated to others, which shown in fig 4.1. This is mainly because composites with highest hardness than the AL7075 alloy display tough confrontation to the sliding wear. Further, due to its high hardness the Tungsten carbide particles restrict the plastic flow of AL7075 matrix during sliding wear. Higher the reinforcement content higher is the shear strain required for plastic flow of AL7075 matrix in the composites. Restriction posed by reinforcements is why the composites have low wear rate. The wear resistance increases with improved dispersion and increasing tungsten carbide and Glass fiber content in the metal matrix [15].

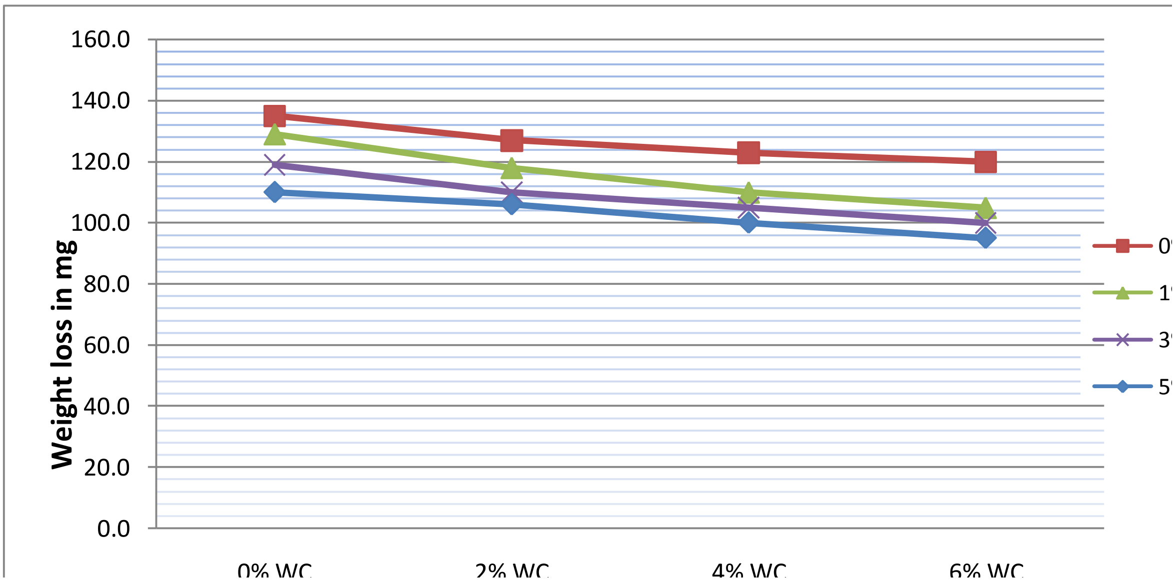

Fig. 4.1 Effect of reinforcement content on wear rate of Al7075 hybrid composites

4.1.2 Effect of load on wear rate

Fig. 4.2 shows the effect of load on wear rate of AL7075 alloy and its hybrid composites with fixed sliding velocity of 0.314 m/s. With the increase in load from 20 N to 100 N, the wear rate of all the materials is increasing linearly for all the materials. Highest wear rate was observed for AL7075 for 100N load while that of lowest wear rate was observed for AL7075- AL7075-6%WC-5%E-GF for 20N load. At starting load of 20 N, the hard asperities of offset surface enter the composite pin surface which leads to ploughing and formation of grooves on the matrix surface. Further, the formation of grooves is mainly due to delamination of matrix surface at this load indicates mild and oxidative wear. According to Archard's law, the wear rate of a material is function of applied load that is if the load or pressure applied on the material is increased then the wear rate also increases linearly. With the increase in applied load the asperities of hard counter surface penetrate the soft matrix surface.

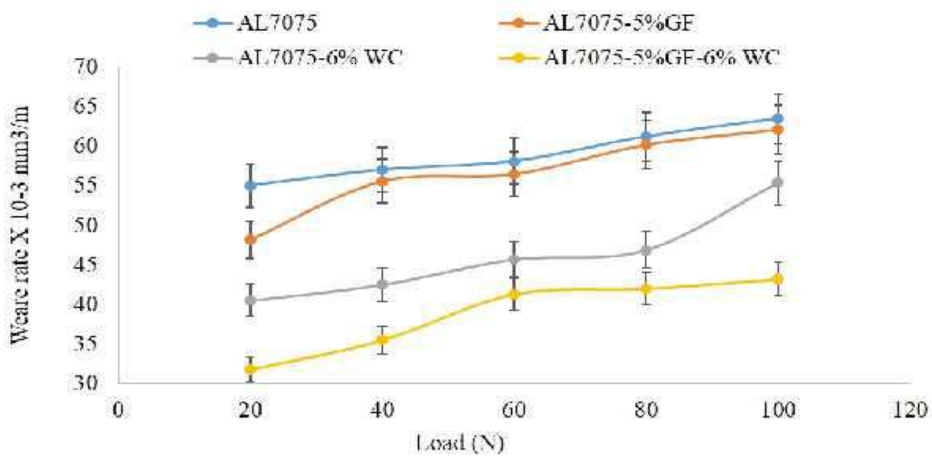

Fig. 4.2 Effect of load on wear rate of Al7075 hybrid composites

4.1.3 Effect of reinforcement on Coefficient of Friction

Fig. 4.3 demonstrates the after effect of Tungsten carbide and Glass fiber content on the coefficient of friction of AL7075 hybrid metal matrix composites. It is seen from the diagram that all the composites have shown lower coefficient of friction when assessed with to that of Al7075 alloy. The lowest coefficient of friction was obtained for Al7075-3%Tungsten carbide-3%E GF composite is almost 40% less that of Al7075 alloy. This is mainly because of presence of homogeneously distributed hybrid reinforcements in the Al7075 matrix material. The reinforcements are dispersed consistently because of virtue of optimum processing conditions adopted during stir casting and dispersing them uniformly. The presence of multiple reinforcements on the surface of the Al7075-Tungsten carbide-E Glass Fiber composite acts as projections which protect the aluminum alloy from having direct contact with the steel surface. Owing to their non- sticking characteristics both the hybrid reinforcements minimizes the contact area and in turn reduces the adhesion of two mating surfaces.

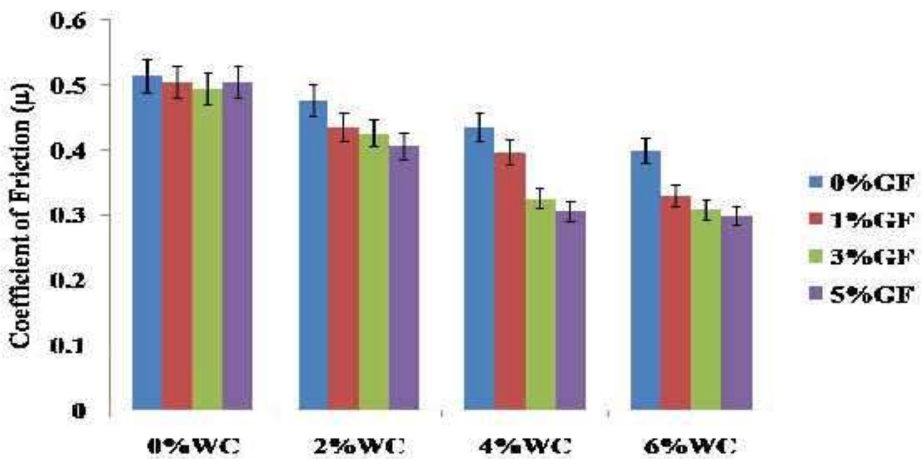

Figure 4.3 Variation of Co-efficient of friction with respect to hybrid reinforcement

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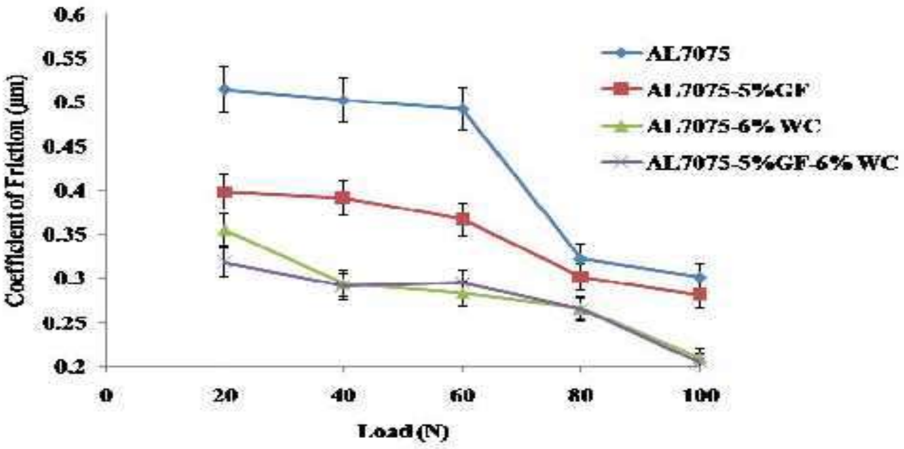

Figure 4.4. Coefficient of friction with respect to load and reinforcements

The reduction in contact area of composite pin and counter surface disc results in lower coefficient of friction. With the increase in Tungsten carbide content from 0% to 6% we are observing the decrease in coefficient of friction by 7.2%, where as in case of E glass fiber, 4.5% is the maximum reduction in coefficient of friction observed. However, lowest coefficient of friction is observed with AL7075-6%Tungsten carbide-5%E GF hybrid composite [16-17].

4.1.3 Effect of load on Coefficient of Friction

Fig. 4.5 demonstrates the influence of load on coefficient of friction of AL7075 and its hybrid composites. It can be seen from the diagram that as the load is expanded from 20 N to 100 N, the coefficient of friction is diminishing for both Al7075 alloy and its hybrid composites. Most minimal coefficient of friction for Al7075-6%WC-5%GF composite. The abatement in the coefficient of friction is largely credited to slippage between the surfaces steel plate and composite pin. As saw in both Al7075 and composites, with the expansion in load the contact area between mating surfaces increases however this will offer raise to the temperature at the interface. This expansion in temperature at the contact surface will prompt softening of this surface which causes the slippage. Because of this slippage there is a diminishment in coefficient of friction in both Al7075 and its hybrid metal matrix composites.

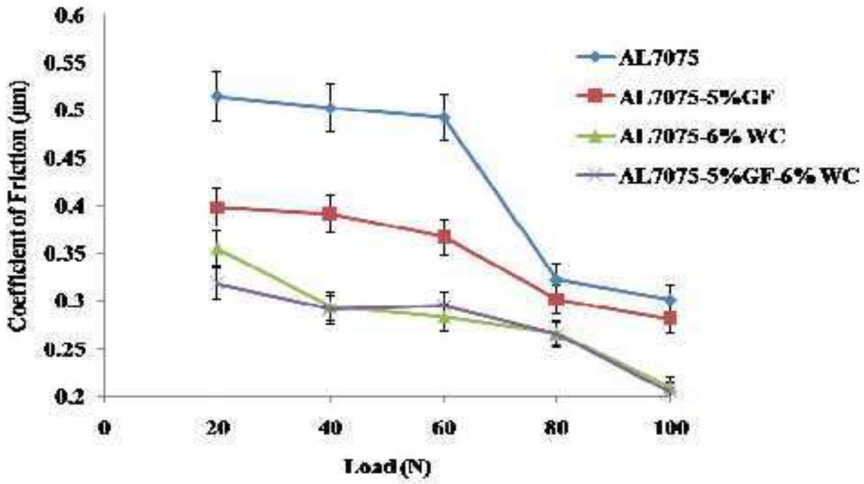

Figure 4.5 Coefficient of friction with respect to load and reinforcements

Fig. 4.6 Coefficient of friction with respect to load and reinforcements. On the differing side the AL7075-6%WC-5%E GF composite showed marginal increase in coefficient of friction for 100 N load when evaluated with that of 80 N load. The likely reason could be elimination of reinforcements from the matrix surface resulting in three body wear which is can cause the coefficient of friction to shoot to the higher level in this composite [18]. Further, it is interesting to note that, under identical test conditions for all the composites studied there is a reduction in the coefficient of friction with increase in load. However, when compared with the E glass fibers, tungsten carbide particles reinforced composites exhibited lower friction coefficient. This may be attributed to excellent lubrication characteristics of tungsten carbide particles, their shape and size which differ from E glass fibers. Further, it is also important to be observed that the significance of hybrid reinforcements is better at lower loads compared to higher load. At higher loads there is no much difference in coefficient of friction values between composites reinforced with single and dual reinforcements. Only a marginal difference is observed at higher loads.

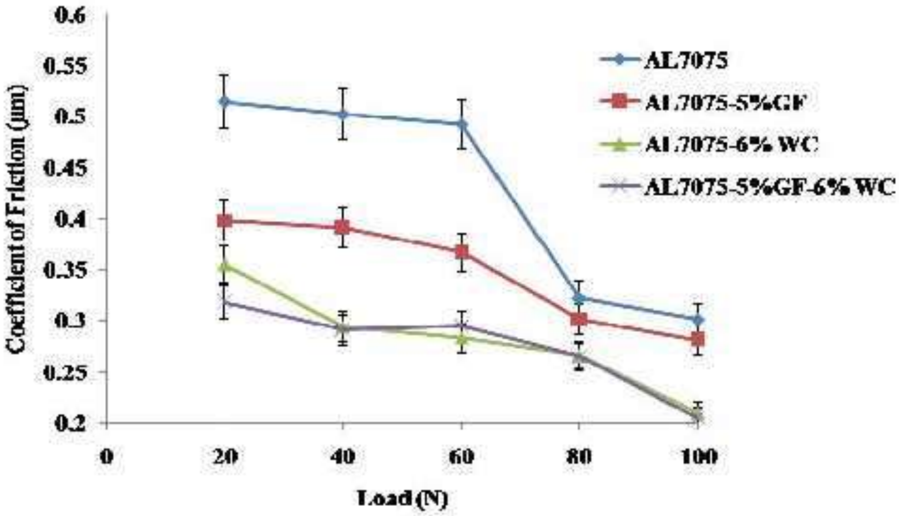

Fig. 4.6 Coefficient of friction with respect to load and reinforcements.

4.1.4 Effect of Sliding Velocity on coefficient of friction

From Fig. 4.7 it can be seen that, with the expansion in sliding speed from 0.314 to 1.570 m/s, there is an increment in coefficient of friction. Highest coefficient of friction is watched for AL7075 composite especially at a sliding speed of 1.570 m/s. most minimal coefficient of friciton was seen for AL7075-6%WC-5%E-GF for 0.314 m/s sliding speed. It is unmistakably observed that, with the expansion in friction coefficient with the expansion in sliding speed can be credited to development of plastic strains. This plastic strain will progresses the bond between the stick surfaces and counter surface which can prompt raised coefficient of friction. The plastic strain will increases with the expansion in sliding speed and the measure of localized adhesion of various reinforcements with the counter surface
plate will be high. This is the reason we are observing higher friction coefficient at higher sliding speeds for all the combinations studied [19].

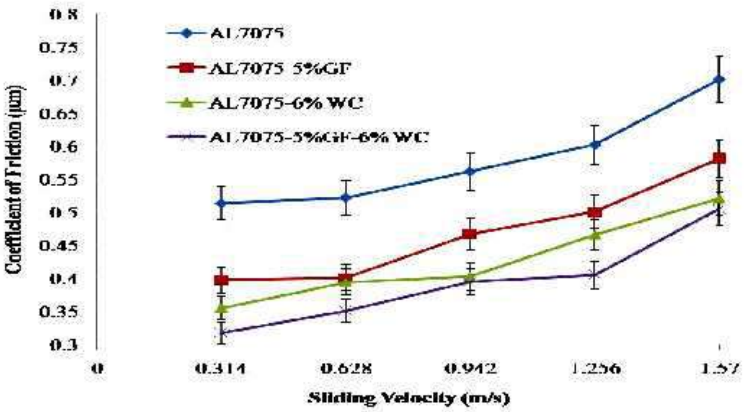

Fig. 4.7 Coefficient of friction with respect to sliding velocity and dual reinforcements

The lesser value of coefficient of friction at reduced sliding speeds can be credited to advancement of thin adherent oxide film at interface. Notwithstanding, as the sliding speed is expanded, the strong lubricating layer gets thickened and may fragment and results in higher coefficient of friction. Further, the heat generated because of expanded sliding speeds is also
results in higher coefficient of friction [20]. Then again this expanded temperature at higher sliding speeds can cause thorough plastic deformation of mating surfaces prompting more asperities intersections, because of it, coefficient of friction by and large increases. The other possible reason for increase in friction coefficient with the increasing sliding velocity is oxidation. As the sliding velocity increases the temperature of the contacting area is also found to be increasing. This increase in temperature can lead to oxidation of the contacting
surfaces which lead to formation of oxide layer. As the temperature of contacting surfaces in increased due to increase in sliding velocity the oxide layer breaks and result in three body wear. So amount of formation of oxide particles will higher with the increasing sliding velocity resulting in higher coefficient of friction. In addition to this the possibility of reinforcements might

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come out of AL7075 surface with the increasing sliding velocity. So along with the oxide particles, these reinforcements can cause third body wear which is why we are observing high coefficient of friction at higher sliding velocities. This is reflected in the increase in friction coefficient values of both AL7075 alloy and its hybrid composites at higher sliding velocities [21].

5 CONCLUSIONS

1. The coefficient of friction of Al7075 alloy and its hybrid composites diminishes with Addition secondary reinforcements. However, a huge reduction in coefficient of friction is seen with dual reinforcements. All the studied hybrid composites shows low coefficient of friction when evaluated with unreinforced alloy. Heat treated alloy and its hybrid composites have shown slightly reduced coefficient of friction when evaluated with unreinforced aluminum alloy and its hybrid composites

2. Wear rate of hybrid composites are reduced when evaluated with matrix aluminum alloy. Addition of hard reinforcements stimulates the reduced wear rate. Further, Heat treatment has resulted in least wear rate of matrix material and hybrid composite under identical test conditions.

3. Adhesion, abrasion and delamination's were dominant wear mechanisms in hybrid metal matrix composites. A remarkable change in wear mechanism is noticed in hybrid composites compared with unreinforced Al7075 alloy.

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DOI: dx.doi.org/10.7324/IJASRE.2018.32627