Friction and Wear Behaviour of Tungsten Carbide and E Glass Fibre reinforced Al7075 based Hybrid composites

Santhosh Kumar.B.M1, D.P.Girish2
1Department of Mechanical Engineering, JSSATE, Bangalore.
2Department of Mechanical Engineering, Government Engineering College, Ramanagaram.

Abstract
Al7075 based hybrid metal matrix composite reinforced with tungsten carbide and E glass fiber particles were fabricated by liquid metallurgy. The developed hybrid composites were subjected microstructure studies, hardness and dry friction and wear tests. Pin-on-disc setup was utilized to perform friction and wear tests over a load range of 20-100N and sliding speeds of 0.314-1.57m/s. Micro-structure affirms uniform scattering of reinforced particles. Hybrid composites show higher hardness, enhanced friction and wear characteristics in the presence of E Glass fiber and tungsten carbide particles when evaluated with the unreinforced alloy.

Keywords: Hybrid Composites, Al7075, E-Glass fiber, Tungsten Carbide, Friction, wear

1.0 Introduction
Metal matrix composites (MMCs) constitute an imperative class of design and weight-productive auxiliary materials that are empowering each circle of engineering applications. In recent years, metal matrix composites are gaining tremendous popularity over the conventional metals/alloys in various sectors such as automobile, aerospace and sports owing to the fact that properties can be tailored as per ones requirement- A uniqueness of composites. The combinations of properties are obtained only by combining multiple materials and selecting the right type of reinforcements which can be developed by using different metal matrices such as copper, aluminum, magnesium, Titanium etc. Among various types of metal matrices, Aluminum and its alloys have magnificent physical properties combined with excellent corrosion resistance. Al7075 is a very well-known choice as an alloy to get ready metal matrix composites inferable from their better formability attributes and alternative of alteration of the strength of composites by embracing ideal heat treatment. In the recent years researchers have extensively focused on developing and characterization of aluminum based hybrid metal matrix composites[1-4].

In another work Basavarajappa et al [5] deliberated the effect of sliding speed on wear behaviour of Al2219/SiC/Gr hybrid composites. The wear rate for all the materials that is unreinforced alloy and hybrid composites was found to be same up to sliding velocity of 3 m/s. After that there was abrupt increase in the wear rate of unreinforced alloy when evaluated with that of hybrid composite. Rana et al. [6] have studied the friction co-efficient existing between Al-1.5% Mg reinforced with SiC and a tool steel counter face. The co-efficient of friction decreases with addition of SiCcontent. Roy et al. [7] have characterized friction behavior of aluminum composites reinforced with SiC, TiC and TiB2. Results indicate that a maximum reduction of 30% was observed for composite when evaluated with unreinforced alloy. The type and size of the reinforcement phase were reported to have a negligible influence on the friction co-efficient.

Various types of reinforcements used to produce composites such as SiC, TiO2, Al2O3, TiB2, TiC [2, 8-10].Tungsten Carbide (WC) is also used as reinforcement’s owing to their highest hardness, low CTE, temperature stability and chemical inertness [11-12]. On the other
hand, E-Glass is a fiber type inexpensive reinforcement which possess lower density, high hardness and fracture toughness [13-14]. Meager information available on the combined effect of glass fiber and Tungsten carbide on tribological characteristics of Al7075 hybrid metal matrix composites. In view of the above facts, current study emphases on study of tribological behaviour of E glass fiber and tungsten carbide reinforced Aluminum 7075 metal matrix composite.

2.0 Materials and Methods

Aluminum 7075 alloy was used as matrix material. Table 1 demonstrates chemical composition of Al7075 alloy.

Table: 1 Al7075 alloy composition

| Element | Wt. % |
|---------|-------|
| Cu      | 1.8   |
| Cr      | 0.2   |
| Mn      | 0.4   |
| Mg      | 1.9   |
| Si      | 0.5   |
| Ti      | 0.15  |
| Zn      | 3.25  |
| Fe      | 0.5   |
| Al      | Balance |

Chopped E-glass fiber and tungsten carbide particles were used as hybrid reinforcements in Al7075 matrix material. 0wt%, 1wt%, 3wt% and 5wt% E-glass fiber was incorporated in the matrix alloy for synthesizing composites whereas tungsten carbide particles were varied from zero to 6wt% in steps of 2wt%. Composites were fabricated by liquefying Al7075 alloy in an electrical resistance furnace utilizing clay graphite pot. In a batch, 3 Kgs of Al7075 ingots were used for composite preparation. The furnace temperature was maintained at 750 ‘C for melting of Al7075 alloy. Hexachloroethane degassing billets were added to remove entrapped gases. The mixing blade was rotated at 250 rpm and a vortex was made in the liquid aluminum. The slag was taken away from entering the molds while pouring through the spout. Hardness tests were conducted utilizing Brinell hardness analyzer. A load of 10 kg were applied into metalographically polished samples of Al7075 alloy and its hybrid composites. Five readings were considered and the average values have been ascertained for each sample. The specimen for friction and wear studies have been machined and examined in computerized pin on disc testing system. Tests were accompanied for specific loads and speeds at constant track radius (135mm) and fixed sliding distance (1KM). The mating surface of the disc and pin turned into cleaned with the aid of using acetone. The wear samples (8 mmØX15 mm) were tried in agreement with ASTM G99 standard procedure utilizing a pin-on-disc sliding wear testing machine. The test specimen was fixed and positioned against the turning EN24 steel plate.

3.0 Results and Discussions

3.1 Microstructure

Fig.3.1 (a-b) displays optical micrographs of Cast Al7075 and Al7075+E-glass fiber+WC hybrid composites. It is observed that dispersion of reinforced phase is fairly uniform. Further, it is visible from the micrographs that there exists good bond between Al7075 matrix alloy and E-glass fibers and tungsten carbide particles. There are no visible defects or porosities associated with reinforced particles indicating good quality of composites.
3.1a Al7075 matrix alloy
3.1b Al7075+2% E glass fibre+3% WC

3.2 Hardness
Fig.3.2 shows variation of hardness of Al7075+E-glass fiber+WC hybrid composite with increase in tungsten carbide particles at constant percentage of E-glass fiber. It is observed that, for a given percentage of E-glass fibers, there is a continuous increase in the hardness of the hybrid metal matrix composites with increase in tungsten carbide particle. In the absence of E-glass fiber a maximum hardness is noticed for 6wt% WC particles (Al7075+6%WC+0%E-glass fiber). In the presence of E-glass fiber, the maximum hardness recorded with increase in the percentage of tungsten carbide alone from 0 to 6wt%, a maximum improvement is observed, whereas with addition of E-glass fibers from 0% to 5% with corresponding tungsten carbide content a maximum hardness was recorded Al7075+4%WC+3%E-glass fiber hybrid composite. Among all the combinations of hybrid composites studied, the highest hardness was recorded for Al7075+4%WC+3% E-glass fiber hybrid metal matrix composites.

3.3 Coefficient of Friction
Fig.3.3 demonstrates the after effect of Tungsten carbide and Glass fiber content on the friction of AL7075 hybrid composites. It is seen from the graph that all the composites have shown lower friction values when assessed with to that of AL7075. The lowest friction values was obtained for AL7075-3%Tungsten carbide-3%E GF composite is almost 40% less that of AL7075. 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 GF 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.

Fig. 3.4 demonstrates the influence of load on frictional values of AL7075 and its hybrid composites. It can be seen from the graph that as the load is expanded from 20 N to 100 N, the friction coefficient is diminishing for both AL7075 and hybrid combinations. Most minimal friction coefficient was seen 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.

From Fig. 3.5 it can be seen that, with the expansion in sliding speed from 0.314 to 1.570 m/s, there is an increment in frictional values. Highest friction coefficient was recorded for AL7075 composite especially at 1.570 m/s. Most minimal coefficient of friction was seen for AL7075-6%WC-5%E GF for 0.314 m/s sliding speed. It is observed that, with the expansion in friction coefficient with the increase 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 [15].

3.4 Adhesive Wear

Fig. 3.6 displays the influence 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 from Fig. 3.6 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. 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. Fig. 5.7 demonstrates the influence of load on wear rate of AL7075 and 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. Maximum wear rate was recorded for AL7075 for 100 N load while that of
The lowest wear rate was observed for Al7075-AL7075-6%WC-5%E-GF for 20 N 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, if the load or pressure applied on the material is increased then the wear rate also increases linearly. With rise in applied load the asperities of hard counter surface penetrate the soft matrix surface. This can lead into higher material removal rate from the soft matrix surface. Overall when compared to that of Al7075 alloy, the hybrid composites displayed lower wear rate at all loading conditions. This is mainly due to high hardness of both the reinforcement particles which enables the composites to sustain higher loads and restrict the flow of Al7075 matrix during sliding. In addition to this the strong bonding of matrix with reinforcement is the one more reason for low wear rate of hybrid composites.

Fig. 3.6 shows the impact of velocity on the wear behaviour of Al7075 alloy and its hybrid combinations. The sliding speed was varied from 0.314 to 1.570 m/s by keeping load of 20 N constant for all the sliding tests. It was seen that with the enhanced sliding speed the wear rate were increased. The maximum wear rate was recorded for Al7075 alloy at sliding velocity of 1.570 m/s while lowest wear rate was obtained for hybrid composites with Al7075-6%WC-5%E-GF at 0.314 m/s. The increase in wear rate is almost 15% for increase in sliding velocity is observed for alloy. When we compare the wear rate of both alloy and hybrid composite with Al7075-6%WC-5%E-GF at 0.314 and 1.570 m/s, the increase in wear rate is about 40% and 53% respectively. The significant reduction in wear rate at all sliding velocities for composites is mainly due the presence of hybrid reinforcement’s.

4. Conclusions
Friction coefficient of Al7075 alloy decreases with addition of tungsten carbide and E glass fiber. Coefficient of friction decreases with load and exhibits higher values with sliding speed. Wear rate of hybrid materials were minimal when evaluated with aluminum. Addition of hard reinforcements stimulates the reduced wear rate under all loads and sliding speeds.

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