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Study of Tribological behaviour of Aluminium 7075 Metal Matrix Composite Reinforced with Titanium Carbide, Graphite and Egg Shell Particulates

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Abstract : In the present study an effort has been made to study the wear behaviour of alunimium 7075 which is reinforced with Titanium carbide (TiC), Graphite (Gr) and Egg Shell particulates (ESP). Castings are produced by using stir casting process. Weight percentage of graphite is varied from 1 wt. % to 3 wt. % in step of one while keeping constant 2 wt. % of Titanium Carbide and constant 1 wt. % of Graphite. Wear tests are carried out to study the wear behaviour of the prepared samples by using pin on disc apparatus. Wear tests are conducted in two sets, one by keeping constant speed of 300 rpm and by varying load from 10 N to 30 N in step of 10 N. Another set of wear test is carried out by keeping constant load of 40 N and by varying speed from 300 rpm to 500 rpm in step of 100 rpm. Morphology analysis of worn-out surfaces is carried out at different wear parameters by using inverted optical microscope to study the surface morphology of worn-out surfaces. From the study it was observed that weight percentage of ESP has a great influence on the wear behaviour of Al7075 MMC.

Keywords: Al7075, Metal Matrix Composites, Egg Shell Particulates, Graphite Titanium Carbide

I. INTRODUCTION

Metal matrix composite (MMC) is a combined product of matrix phase of metal and reinforcement phase. In MMCs, the commonly used matrix elements are copper (Cu), aluminium (Al), magnesium (Mg), Titanium (Ti), etc. [1]. The combination of aluminium metal matrix phase and reinforcement phase designates aluminium MMCs. Favorable properties of MMCs like higher specific strength, better strength retention at higher temperatures, better fatigue resistance, better corrosion and wear resistance, improved damping capabilities, better thermal and electrical conductivity, lower coefficient of thermal expansion, etc., have found potential application in various sectors like structural, automobile, aerospace, space and defense [3, 4]. Reinforcements such as Tungsten (W), Silicon carbide (SiC), Titanium carbide (TiC), Boron (B), Graphite (C), Aluminum oxide (Al_2O_3), Zirconium oxide (ZrO_2), fly ash etc. are currently being used in developing advanced MMCs with enhanced capabilities [5, 6].

Low-cost hybrid reinforcements, essentially industry by-products that are readily available and naturally reusable are currently being used in processing of hybrid composites. Hybridization is a process of incorporating two or more reinforcements into a metal matrix so as to obtain better stiffness, high strength to weight ratio and other improved mechanical properties [7]. Hybrid composites primarily comprises of one matrix and two or more reinforcements and have the potential to substitute single reinforced composites with their improved properties. Out of several processing techniques available, namely, Solid phase fabrication techniques (Diffusion bonding and Powder metallurgy) and Liquid phase fabrication techniques (Stir casting, Spray casting and Squeeze casting), Stir casting is preferred because of flexibility, cost-effectiveness and best suitable for mass production [8].

Although, a lot of research is being carried out on the use of MMCs in different fields to meet the future engineering challenges, exclusive research is still required to explore the use of hybrid Aluminium 7075 MMCs prepared with different reinforcements at efficient as well as economical scale.

2. Fabrication of Aluminium Hybrid MMC:

For the experimental study Aluminium 7075 is selected as matrix material as it is one of the most widely used commercially available form of aluminum. The chemical composition of aluminium 7075 alloy is shown in table 1. The aluminium 7075 is supplied by Fenfee Metallurgicals in the form of ingots, which is shown in figure 1.

Figure 1. Aluminium 7075 ingots

Table 1. Chemical Composition of Aluminium 7075

Component	Zn	Mg	Cu	Cr	Fe	Si	Mn	Ti	Al
Wt. %	5.5	2.5	1.6	0.15	0.5	0.4	0.3	0.2	Balance

In the present study Titanium carbide (TiC), Graphite (Gr) and Egg Shell Particulates (ESP) are used as reinforcement material to form a hybrid aluminium 7075 metal matrix composite. Titanium carbide is procured from Parshwamani metals Mumbai in the form of powder of size 40 microns. Graphite is procured in the form of powder of size 100 micron from Vasa Scientific Co. Bengaluru.

Egg Shell Particulate is the one more reinforcement material used in the fabrication of Al7075 hybrid metal matrix composite. White Egg shells are collected from hotels and restaurants and are dried under sunlight for about 3 to 4 days. Dried egg shells are powdered and these powdered egg shells are sieved by using sand sieve shaker to obtain a uniform sized egg shell particles of 106 micron size. Figure 2 below shows all the three reinforcement materials used in the fabrication of Al7075 hybrid metal matrix composite.

Figure 2. Reinforcement materials (a) TiC, (b) Gr, (c) ESP

Stir casting is the fabrication method used in this study to fabricate aluminium 7075 hybrid metal matrix composite since stir casting is one of the most powerful fabrication techniques now a days used in fabrication of metal matrix composites. Stir casting method is widely used to fabricate metal matrix composites because it is one of the simple and low-cost fabrication technique and can get uniform distribution of reinforcement particles in the matrix phase. Total 4 castings are prepared in the form of circular rod of diameter 26 mm and length 300 mm. Weight percentage of Egg Shell Particulate is varied from 1 % to 3 % in steps of 1 by keeping constant 2 wt. % of Titanium carbide and constant 1 wt. % of graphite particles. Figure 3 below shows the stir casting setup and the cast Al7075 MMC rods.

Figure 3. Stir casting setup and Casted Al7075 MMC rods

3. Wear Test:

In the present work an attempt has been made to investigate the wear properties of the material by using pin on disc apparatus. The tests were conducted under dry sliding conditions as per ASTM G99-05 standards. The composite test specimens were prepared as pins with a regular dimension of 8 mm diameter and 30 mm height. The rubbing surfaces of the specimen are prepared perfectly flat, cleaned and polished. The experiments were carried out for different loads of 10, 20 & 30 N by keeping constant speed of 300 rpm and variable speeds of 300, 400 & 500 rpm with constant load of 40 N, for a sliding distance of 1 km. The track diameter of the disc maintained is 60 mm for all the trials. After each run, the sample was cleaned by acetone to remove the burrs on the sample and then the sample was weighed by a digital balance having least count of 1 mg. In order to obtain more precise values of the wear rate, each trial was performed thrice and the average value of the wear rate was then used for further calculations so as to reduce the error. The process was repeated for all the combinations of the composites. The disc was also cleaned by acetone for every trial.

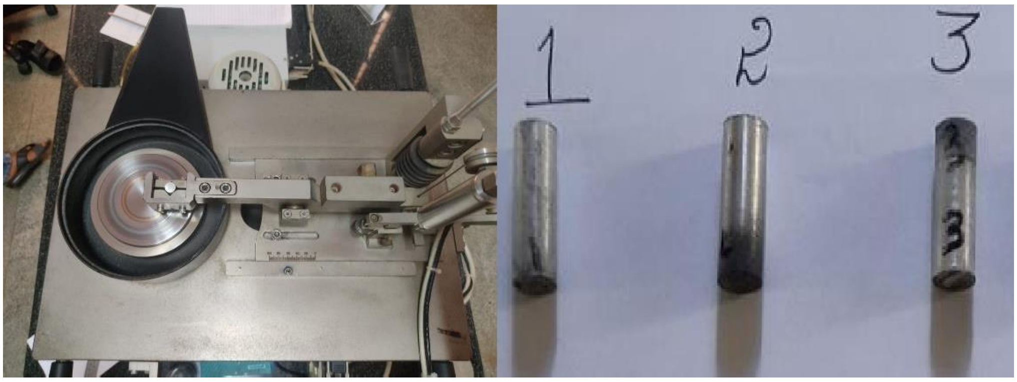

Figure 4. Pin on disc apparatus and prepared specimens for wear test

4. Result and discussion:

4.1 Wear rate & Coefficient of friction:

Two sets of wear tests are conducted, one by keeping the speed constant and varying load, another by keeping load constant and varying speed. In the first set 300 rpm speed is kept constant and the load is varied from 10 N to 30 N in steps of 10 N. In the next set 40 N load is kept constant and the speed is varied from 300 rpm to 500 rpm in steps of 100 rpm. In both the set the sliding distance of 1 km and track diameter of 60 mm is kept constant. Results are as tabulated in the below table. The wear rate is calculated by using the following equation.

$$K = \frac{\Delta w}{F * \rho * L} \qquad (1)$$

Where,

Δw = Weight loss in grams

F = Load applied in Newton

ρ = Density in g/cc

L = Sliding distance in meter

K = Wear rate in mm^3/Nm

Table 2. Wear rate and coefficient of friction under constant speed of 300 rpm

Specimen No	Load (N)	Initial Weight W_1(gm)	Final Weight W_2(gm)	Weight Loss W_1-W_2(gm)	Wear Rate mm^3/Nm	Coefficient of Friction
1 (Al7075 + 2 % Tic + 1% Gr + 1 % ESP)	10	6.262	6.26	0.002	7.11744E-05	0.5008
	20	6.26	6.256	0.004	7.11744E-05	0.4807
	30	6.256	6.254	0.002	2.37248E-05	0.4465
2 (Al7075 + 2 % Tic + 1% Gr + 2 % ESP)	10	6.581	6.576	0.005	1.77936E-04	0.414
	20	6.576	6.572	0.004	7.11744E-05	0.4619
	30	6.572	6.567	0.005	5.9312E-05	0.4054
3 (Al7075 + 2 % Tic + 1% Gr + 3 % ESP)	10	7.181	7.178	0.003	1.06762E-04	0.1571
	20	7.178	7.169	0.009	1.60142E-04	0.2555
	30	7.169	7.156	0.013	1.54211E-04	0.2686

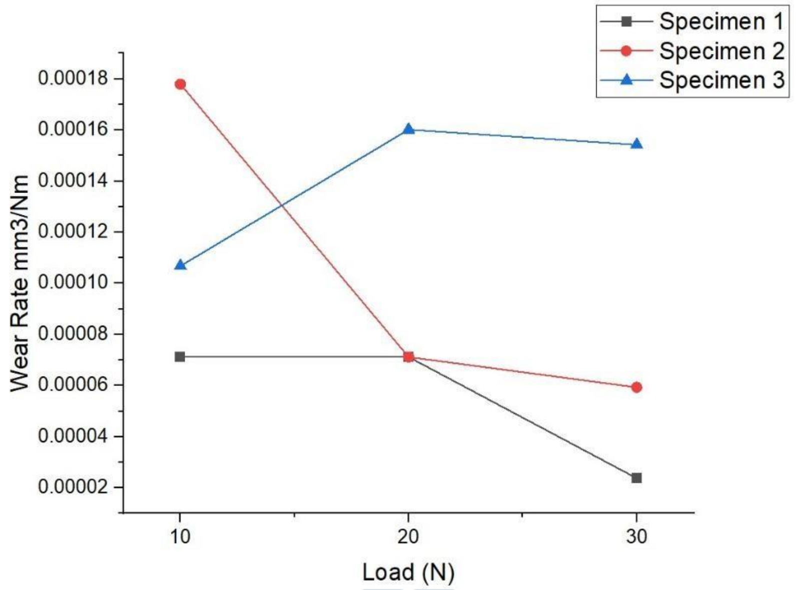

Figure 5. Wear rate under constant speed of 300 rpm

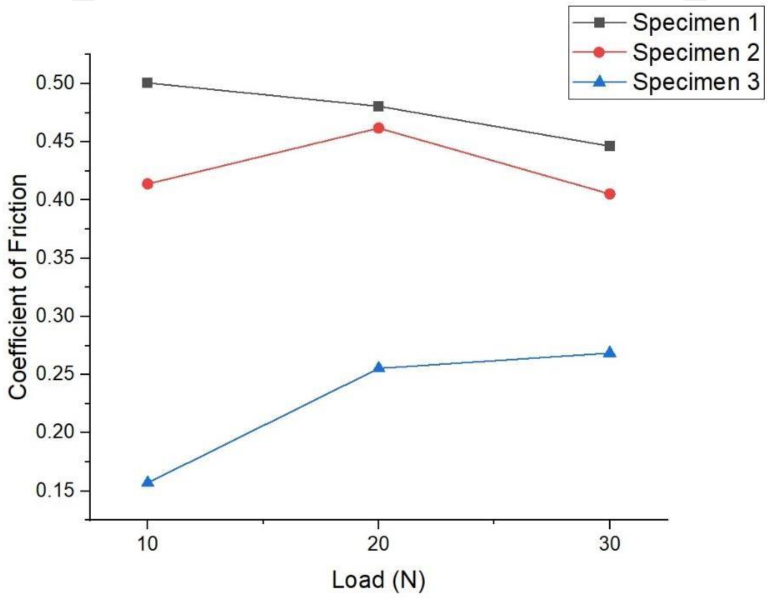

Figure 6. Coefficient of friction under constant speed of 300 rpm

Table 3 Wear rate and coefficient of friction under constant load of 40 N

Specimen No	Speed (rpm)	Initial Weight W_1(gm)	Final Weight W_2(gm)	Weight Loss W_1-W_2(gm)	Wear Rate mm^3/Nm	Coefficient of Friction
1 (Al7075 + 2 % Tic + 1% Gr + 1 % ESP)	300	6.547	6.532	0.015	0.000133452	0.125
	400	6.532	6.514	0.018	0.000160142	0.2403
	500	6.514	6.502	0.012	0.000106762	0.3349
2 (Al7075 + 2 % Tic + 1% Gr + 2 % ESP)	300	7.145	7.124	0.021	0.000186833	0.1035
	400	7.124	7. 11	0.014	0.000124555	0.3443
	500	7.11	7.099	0.011	9.78648E-05	0.3415
3 (Al7075 + 2 % Tic + 1% Gr + 3 % ESP)	300	5.844	5.832	0.012	0.000106762	0.1039
	400	5.832	5.823	0.009	8.00712E-05	0.3195
	500	5.823	5.812	0.011	9.78648E-05	0.3173

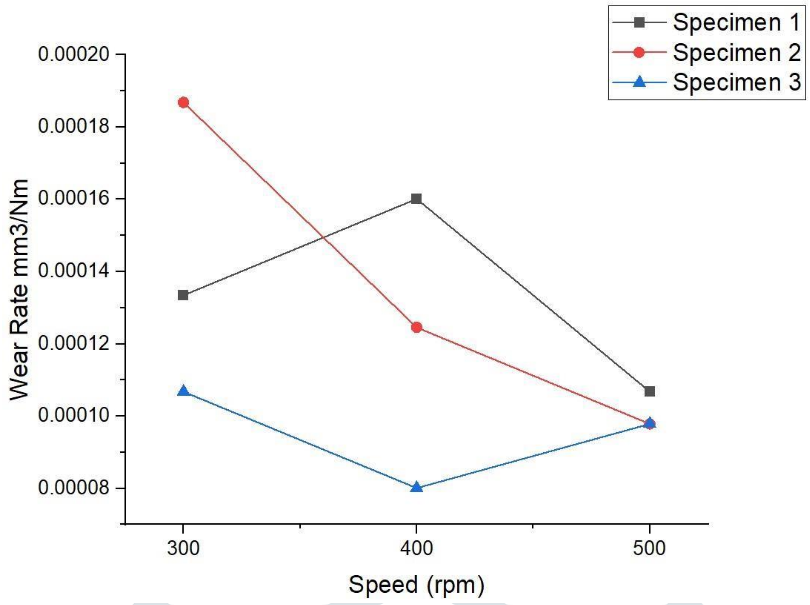

Figure 7. Wear rate under constant load of 40 N

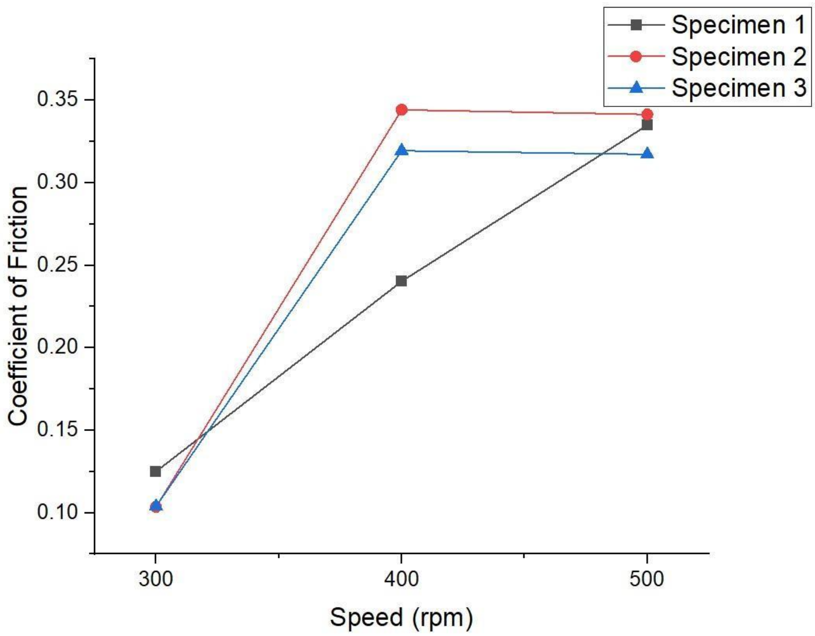

Figure 8. Coefficient of friction under constant load of 40 N

4.2 ***Morphology of worn surfaces:***

Morphology analysis of worn surfaces of Al7075 MMC with reinforcement was carried out at different wear parameters by using inverted optical microscope. Optical micrographs of some worn out surfaces are illustrated in figure 9.

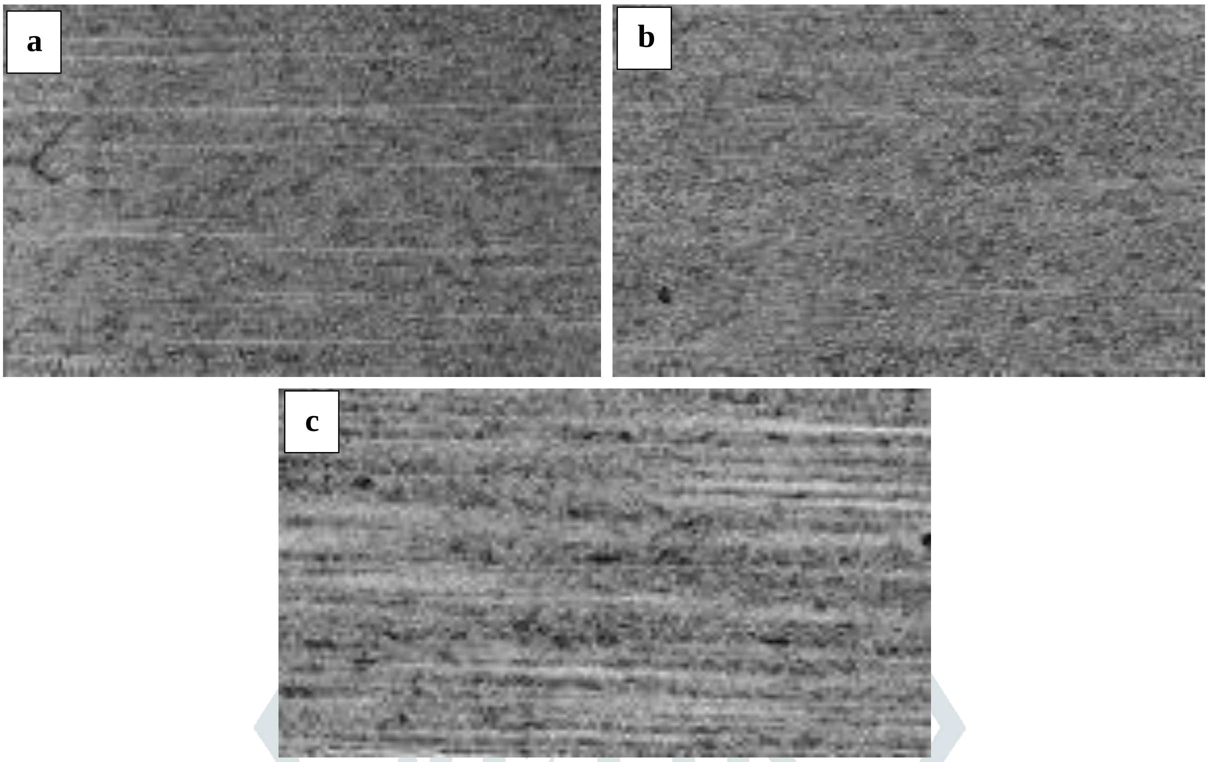

Figure 9. Optical micrographs of worn surfaces (a) Specimen 1, (b) Specimen 2, (c) Specimen 3

5. Conclusion:

The following conclusions are drawn from the study of wear behaviour of Aluminium 7075 MMC reinforced with Titanium Carbide, Graphite and Egg Shell Particulates.

1. Stir casting fabrication technique is found to be effectively adopted for the casting of Aluminium 7075 MMC with reinforcement.
2. Optical micrographs of worn out surfaces reveals the formation of small and very thin grooves due to plastic deformation of Al7075 MMC at different experimental conditions.
3. Under constant speed of 300 rpm the wear rate increases as the composition of ESP is increased from 1 wt. % to 3 wt. % and as the load increases from 10 N to 30 N. At the same time the coefficient of friction gets reduced as the percentage of ESP is increased in the Al7075 MMC.
4. Under constant load of 40 N and varying speed of 300 rpm to 500 rpm the wear rate decreases as the percentage of ESP increases from 1 wt. % to 3 wt. % also the coefficient of friction increased when the Percentage of ESP is increased in the Al7075 MMC

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