Study on Wear Properties of Al7075/SiC/Graphite Hybrid Composites

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Abstract: **A composite material is a 'material system' composed of a combination of two or more micro or macro constituents that differ in form, chemical composition and which are essentially insoluble in each other. Metal matrix composites are become a highly important material in automotive industries due to its light weight and high strength properties. In this investigation, the composites were fabricated using liquid metallurgy route i.e stir casting method. Ceramic particles along with solid lubricating materials were incorporated into aluminium alloy matrix to accomplish reduction in both wear resistance and coefficient of friction. The Al 7075/SiC/graphite hybrid composite was prepared with 3 wt.% graphite particles addition and 3,6, and 9 wt.% of SiC. The study of wear characteristics on Al 7075/SiC/Graphite hybrid composite were carried out. The wear properties of the hybrid composites containing graphite exhibited the superior wear-resistance properties.**

Keywords: Hybrid Mmc, Stir Casting, Wear

I.INTRODUCTION

Aluminum metal matrix composites (AMMC) have emerged as a material for advanced automobile, aerospace and marine applications. It possesses properties like high specific strength, high stiffness, increased fatigue resistance, good wear resistance at elevated temperatures, excellent corrosion resistance, and high temperature durability [1-3]. These composites are alternatives to the traditional engineering alloys. The suitability of MMCs as a promising replacement depends on the ability of synthesizing them with consistent reproducibility in microstructure and properties. These newer generation materials have an increased strength to weight ratio. They can be used in automobile applications like brake rotors, piston rings, etc. [4-7].

Wear is one of the important phenomena that takes place at a materials interface metal matrix composites (MMCs) with reinforcement of hard particles that offer superior performance and wear resistance [8]. AMMCs reinforced with particles of Graphite have been reported to be possessing better wear characteristics owing to the reduced wear because of formation of a thin layer of Graphite particles, which prevents metal to metal contact of the sliding surfaces.

Generally lubricant is externally added to reduce the wear. This poses the problem when the materials need the periodic applications of lubricant particularly to wear parts which are difficult to access. For such applications self-lubricating materials are preferred because the solid lubricant contained in them can be automatically released during the wear process to reduce the wear. Graphite is one of the most widely used solid lubricant materials. Earlier researchers [9-12] have already focused their investigation on applications of aluminium graphite composite.

There are also earlier reports from some investigators [13-14] who identified the trend that aluminium graphite composite containing the small amount of graphite exhibit superior wear properties over the base alloys. The limitation with the aluminium graphite composite is in using graphite as a solid lubricant whose introduction results in the loss of strength of the composite.

S. Kassim et al. [15] reported that the abrasive wear resistance of the alloy is increased as SiCp reinforcement content increases. Y. Sahin et al. have observed significant increase in wear resistance up to 10% addition of SiC and a stable value between 10–55% for Al–SiC composites produced by vacuum infiltration [16].

Addition of SiC particulates increases both mechanical strength and wear resistance of Al alloy. But the consequent increase in hardness makes the machining difficult [17]. On the other hand, addition of Graphite particulates facilitates easy machining and results in reduced wear of Al–Graphite composites compared to Al alloy. But high amount of Graphite may result in increase of wear due to decrease in fracture toughness with increase in % reinforcement of Graphite particulates as observed by Ted Guo and Tsao [18].

S. Suresha and B.K. Sridhara [19] investigated the tribological behaviour of the hybrid composites obtained using a stir-casting procedure, with variable SiC and Graphite amounts (0–5 %) and the total ratio of 10 %. K. Ravindran et al. [20] investigated the tribological behaviour of the hybrid composites with aluminium alloy Al 2024 bases. The hybrid composites were obtained with powder metallurgy using 5 % of SiC and (0. 5 or 10) % of Graphite. Hybrid composite Al/SiC/Gr (5 % SiC and 5 % Gr) showed the best tribological characteristics, while a further increase in the graphite amount increased the wear.

II.EXPERIMENTAL PROCEDURE

Al7075 was selected as matrix material due to its excellent casting properties, strength, formability, and heat treatable properties. The Chemical Composition of Al7075 is shown in Table.1. Graphite and SiC particles sizes of around 20-30 µm and purity of approx 98% were used as reinforcement material in Al7075 matrix material.

Table.1.Chemical Composition of Al 7075 (wt%)

Element	Zn	Cu	Mg	Si	Fe
Wt.%	5.8	1.5	2.4	0.09	0.36
Element	Fe	Mn	Cr	Ti	Al
Wt%	0.36	0.07	0.21	0.05	89.52

A conventional casting route was used for fabricating the composites. The appropriate weight of the aluminium alloy was charged in a graphite crucible and was heated in an electrical furnace. The reinforcement particles were preheated at 750°C in a separate furnace. After melting the charge in the furnace, the preheated particles were added and the mixed charge was stirred at 800 rpm for ten minutes by using an electric motor during which the temperature was kept constant at 800°C. Due to the stirring action, the melted aluminium alloy split into droplets due to the shear forces induced by the impeller at the presence of graphite. Now the charge was evacuated from the crucible into a steel mould and it was solidified. The composites were fabricated at 3, 6, and 9 wt.% of SiC and and 3 wt % of Graphite.

WEAR TEST:

From cast plate, a small portion of dimension 2×2×10 cm^3 were cut and then it was machined to make the cylindrical pin of having dimension 6mm diameter and 35 mm length Fig.1. The wear and frictional tests were carried out on pin on disc apparatus (Model: TR-20LM-M5). All the wear tests were carried out as per ASTM G-99 standard under dry condition at room temperature.

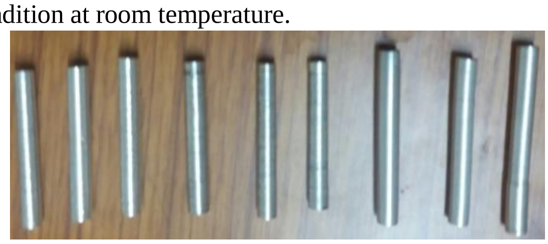


Fig.1.Pin for wear test

III.RESULTS AND DISCUSSION

Based on the tabulated results, various graphs are plotted and presented in **Graph.1 to Graph.4** for different percentage of reinforcement (SiC) under different test conditions. **Graph.1** shows the variation of wear with sliding distance at constant load (20N) and170 rpm. It is seen from the plots that as sliding distance increases the wear of the hybrid composite and Al 7075 alloy exhibited decreasing trend. This was due to that initially both the surfaces were associated with a large number of sharp asperities, and contact between the two surfaces was taken place primarily at these points. During the preliminary wear process, influence of low applied loads (20N) and low speeds (0.8 m/s) were identified in the form of smoothness in work material and miniature lubricant layer in between work material and counter surface. As the asperities were very sharp in nature, the effective stress on these sharp points might be more than the elastic stress, and subsequently these sharp asperities were plastically deformed at their contact points, except the partially projected points of the reinforcement. The plastically deformed surface will fill the valley of the material in both pin and the counter face during the course of action and there was a possibility of fracturing a few asperities on both the surfaces leading to very fine debris. The asperities of the sliding pin surface were come in contact with the steel disc surface and work hardening of the matrix material takes place under the applied load and speed. Consequently, the wear of specimen reduced for high sliding distance. Nature of graph almost matches with the experiment performed by Wang [21].

Graph.2 shows variation of wear with sliding velocity. The plot shows that the wear was increased with rise of speed. When the speed was increased, the ploughed surface of the counter face (Fe) will react and formFe_3O_4 and SiC particles will crush and form very minute particles. The Fe_3O_4, Fe and minute fractured particles of the SiC form a layer between the work hardened pin and the counter face and reduces the wear rate up to a speed 0.6 m/s. When the speed was increased up to 1 m/s the surface film will break the sub surface, work material was under severe stress and asperities sliding surface were caused a combination of abrasive and adhesive wear [22].

Graph.3 shows the variation of wear with normal load. It can be observed from the plots that the wear increases with increase in normal load. At high load (30 N) due to increase in the temperature, the surface of the matrix alloy was became smooth and also promotes local yielding and the wear mechanism has changed from abrasion to delamination wear. Due to this large amount of plastic deformation was observed on the surface of the unreinforced alloy. In case of composite material as the load increase to higher values 10 to 30 N, the morphology of the worm surface was gradually changed from fine scratches to district groove. It was inferred that tearing (fracture) causes formation of wear debris at very high load [23].

The effect of graphite on friction coefficient is shown in **Graph.4.** The presence of graphite in the hybrid composite decreases the coefficient of friction. The reduction in the coefficient of friction exhibited by the hybrid composite relative to Al 7075 is due to the release of graphite during their wear process which acted as the solid lubricant [24].
However it is observed that in all cases wear decreases with respect to increase in percentage addition of reinforcement up to 7 %. The subsequent marginal increasing trend of these hybrid composites at 9 wt. % of reinforcement (i.e. SiC) overshooting the wear rate can be the adverse effect of the hard particle addition together with the increasing tendency of crack initiation and propagation at the reinforcement/metal interface.

Table 2: Wear properties of material at different sliding distance
Load: 20N, Sliding speed: 0.8 m/s, RPM: 170

Material	Sliding distance (m)	Time (sec)	W1 (µm)	W2 (µm)	W_{mean} (µm)
Al 7075	250	312	332	340	336
	500	624	198	216	207
	750	936	143	149	146
	1000	1248	91	87	89
Al 7075 + 3% SiC + 3%Gr	250	312	230	222	226
	500	624	140	156	148
	750	936	115	103	109
	1000	1248	68	76	72
Al 7075 + 6% SiC+ 3%Gr	250	312	154	152	153
	500	624	139	137	138
	750	936	105	103	104
	1000	1248	62	70	66
Al 7075 + 9% SiC+ 3%Gr	250	312	183	177	180
	500	624	145	145	145
	750	936	101	111	106
	1000	1248	57	63	60

Table 3: Wear properties of material at different sliding speed
Load: 20N, Sliding distance: 250 m

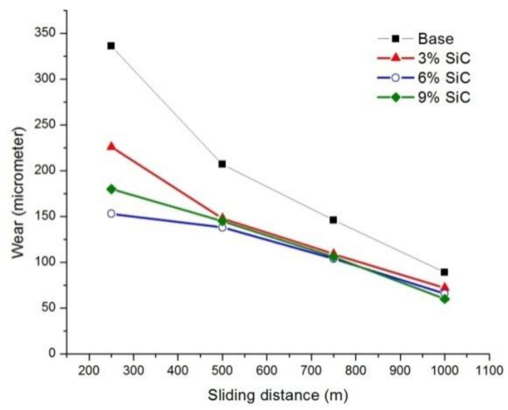
Material	Sliding speed (m/s)	W1 (µm)	W2 (µm)	W_{mean} (µm)
Al 7075	0.6	440	436	438
	0.8	332	336	334
	1	480	490	485
Al 7075 + 3% SiC + 3% Gr	0.6	295	301	298
	0.8	260	258	259
	1	345	349	347
Al 7075 + 6% SiC + 3% Gr	0.6	263	259	261
	0.8	154	158	156
	1	271	267	269
Al 7075 + 9% SiC + 3% Gr	0.6	264	268	266
	0.8	183	181	182
	1	305	305	305

Table 4: Wear properties of material at different load
Sliding speed: 0.8 m/s, sliding distance: 250 m

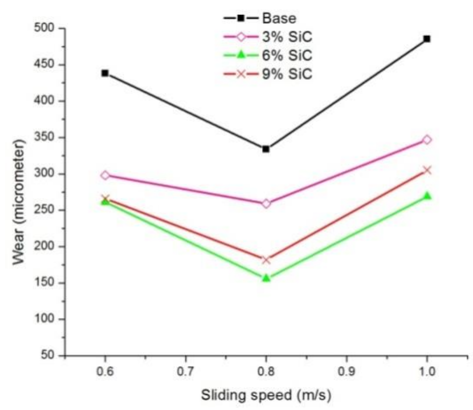
Material	Load (N)	W1 (µm)	W2 (µm)	W_{mean} (µm)
Al 7075	10	44	50	47
	20	71	73	72
	30	81	77	79
Al 7075 + 3% SiC + 3% Gr	10	29	31	30
	20	35	39	37
	30	65	71	68
Al 7075 + 6% SiC + 3% Gr	10	28	26	27
	20	32	28	30
	30	57	61	59
Al 7075 + 9% SiC + 3% Gr	10	47	45	46
	20	57	51	54
	30	63	69	66

Table 5: Coefficient of friction of different material
Load: 20N, Sliding speed: 0.8 m/s, sliding distance: 250 m

Material	$(cof)_1$	$(cof)_2$	$(cof)_{mean}$
Al 7075	0.255	0.285	0.27
Al 7075 + 3% SiC + 3% Gr	0.25	0.19	0.22
Al 7075 + 6% SiC + 3% Gr	0.16	0.18	0.17
Al 7075 + 9% SiC + 3% Gr	0.14	0.12	0.13

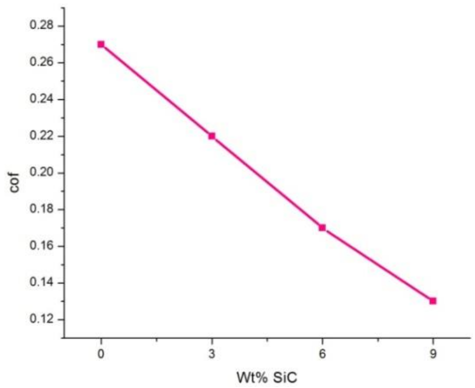


Graph.1: Sliding distance Vs wear

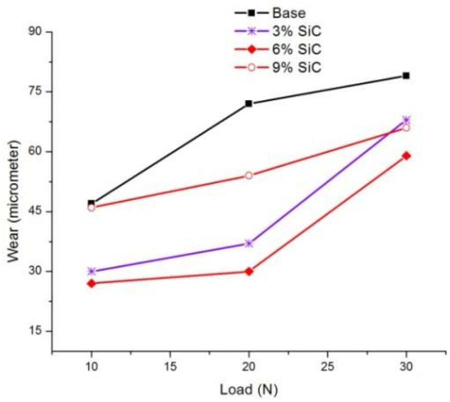


Graph.2: Sliding speed Vs wear

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 01, January-2018



Graph.3: Load Vs wear



Graph.4: Wt %Vs cof

IV.CONCLUSION

In the Present research, hybrid metal matrix composites i.e. Al 7075/SiC/Graphite has been successfully fabricated using stir cast method. Dispersion of SiC and Graphite particles in aluminium matrix reduces the wear of the matrix material. Increase in load increases the wear while it is observed that wear decreases with respect to increase in sliding distance. In case of sliding velocity as it increases the nature of graph shows that wear first decreases then it suddenly increases.

Wear tends to decrease with increasing particle volume content. It also indicates that SiC and graphite addition is beneficial in reducing wear of the aluminium composite. Wear in reinforced alloy is less compare to unreinforced alloy. Coefficient of friction decreases with respect to increase in particle volume content.

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