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Experimental investigation of Wear Characteristics of Aluminium Metal Matrix Composites reinforced with MoS_2 and SiC Particles using Taguchi Method

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Abstract — This paper is investigated the dry sliding wear behavior of Al Metal Matrix Composites reinforced with MoS_2 and SiC particulates. Taguchi's Method is applied to study the effects of reinforcement, load, sliding speed and distance of Al-SiC-MoS_2 hybrid composite made by Stir Casting Method. It is found that addition of SiC particles increases the mechanical strength and wears resistance of Al alloy significantly. In addition to that increase in hardness of the composite resulting the machining a difficult one is reduced by the addition of MoS_2 particles and also results wear reduction.

Keywords – Aluminium, SiC, MoS_2, Composites.

1. INTRODUCTION

Aluminium matrix composites are one of the advanced engineering materials that can be used for a wide range of applications in various industries. In automobile reduction in weight of the automobile structures achieve primary weight saving and if carried to sufficiently great length enable the designer to use small power plant thus achieving substantial improvement in fuel economy.

2. METAL MATRIX COMPOSITES

Conventional engineering materials have limitations in terms of strength, stiffness, coefficient of expansion and density which in turn to focus on advanced materials with different components. A Metal matrix composite is a composite material combination of two or more materials in which modified properties are achieved by systematic combination of different constituents or compositions.

3. LITERATURE REVIEW

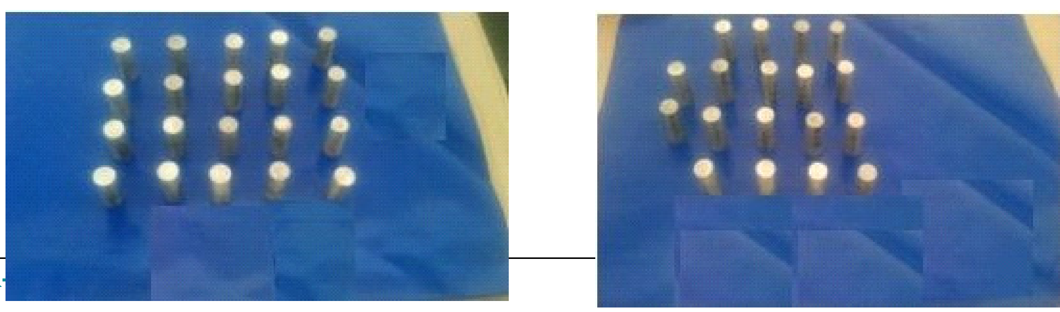
Blaza Stojanovic et al (2017) investigated the tribological behaviour of a hybrid composite with the aluminium alloy base A356 reinforced by 10 wt. % SiC and 5 wt. % of graphite. The optimization of tribological behaviour was conducted through the application of Taguchi method. Tribological examinations were executed on the block on disc tribometer with the variation of two different load values (20 and 30 N), three sliding speed values (0.25, 0.5 and 1 m/s) and three sliding distance values (30, 90 and 150 m). The greatest impact on the wear rate has the load (62.11 %), then the sliding speed (32.88 %), and the least the sliding distance (2.57 %). The interaction of the factors does not have a significant impact on the wear rate. Sandra Veličković et al (2016) analyzed the influence of graphite reinforcement, load and sliding speed with constant sliding distance on tribological behavior of A356 aluminum matrix composites reinforced with 10 wt. % silicon carbide and graphite using the Taguchi design. Tribological tests were performed on a block-on-disc tribometer where the weight percentage of graphite has three variations (0, 3, and 5), as well as load (10 N, 20 N and 30 N) and sliding speed (0.25 m/s, 0.5 m/s, and 1 m/s), with sliding distance of 300 m. It was also found that the greatest impact on specific wear rate has load with the percentage effect of 69.163 %, then sliding speed with 14.426 % and the interaction between wt.% graphite and load. N. Radhika et al (2014) analyzed that Metal matrix composites utilizes the combined properties of the constituent material that finds applications in various fields. They investigated the influence of peak current, flushing pressure and pulse-on time on Electrical Discharge Machining of AlSi10Mg alloy reinforced with 3 wt % graphite and 9 wt % alumina hybrid metal matrix composites. Taguchi's Design of Experiment was used to analyze the machining characteristics of hybrid composites. The most significant parameter of tool wear rate was pulse on time followed by peak current and flushing pressure. Interaction terms also have significant effect on their output responses. M.Walczak et al (2014) presented the results obtained from tribological tests of F3S.20S Aluminium Composite Material containing (20% (v/v) SiC and $AlSi_9Mg$ alloy). This composite is applied as a modern construction material in automotive industry for manufacturing of pistons and brake discs. Significant change in properties of these materials is possible as a result of SiC reinforced particles introduction. K.Umanath et al (2013) presented the wear behavior of Al6061-T6 discontinuously reinforced with silicon carbide (SiC) and Aluminium oxide (Al_2O_3) composite. Empirical relation is established to estimate the wear using statistical regression analysis and analysis of variance (ANOVA). The results indicated that the wear resistance of the 15% hybrid composite is better than that of the 5% composite. The fracture surface of composites shows the ductile tear ridges and cracked SiC and Al_2O_3 particles indicating both ductile and brittle fracture mechanism. K.L.Meen et al (2013) studied that Matrix Composites (MMC's) have evoked a keen interest in recent times for potential applications. In this study Aluminium (Al-6063)/SiC Silicon carbide reinforced particles Metal-Matrix Composites (MMCs) are fabricated by melt-stirring technique. The MMCs bars and circular plates are prepared with varying the reinforced particles by weight fraction ranging from 5%, 10%, 15%, and 20%. The average reinforced particles size of SiC are 220 mesh, 300 mesh, 400 mesh respectively. It was observed that the hardness of the composite is increased with increasing of reinforced particle weight fraction. P.Ravindran et al (2013) made an experimental study that, the tribological behavior of Al 2024–5 wt.% SiC–X wt.% graphite (X = 5 and 10) hybrid nano-composites was produced using powder metallurgy (P/M) technique. The nano-composite with 5 wt. % SiC and 10 wt. % Gr showed the greatest improvement in tribological performance. G.B.Veeresh Kumar et al (2012) investigated that particulate reinforced Al-MMCs exhibits better mechanical properties and improved wear resistance over other conventional alloys. The composites of Al6061 containing 2–6 wt % SiC were prepared using liquid metallurgy route. The hardness and ultimate tensile strength of Al6061–SiC composites were found to increase with increased SiC content in the matrix at the cost of reduced ductility. Imene M. Bayhan et al (2010), made an investigation that Extruded $AlSi_7$ Mg alloy based SiCp reinforced ($AlSi_7$ Mg/SiCp) composites and the matrix alloy wear were tested on a pin on disk type tester. In this concern, the average value of optimum reinforcement contents and the average value of optimum sliding distances of$AlSi_7$ Mg/SiCp composites minimizing the wear rate were found as 13% and 595 m, respectively. Also the average value of optimum reinforcement content minimizing the weight loss was found as 13%. J.Luo et al (2011) studied the rotational fretting wear behaviors of the bonded MoS_2 solid lubricant coating and its substrate steel were comparatively studied under varied angular displacement amplitudes, constant normal load, and rotational speed. The experimental results showed MoS_2 changed the fretting running regimes of substrate. The friction coefficients of MoS_2 were lower than those of the substrate. For MoS_2, the damage in partial slip regime was very slight. The damage mechanism of the coating in slip 12 regimes was main abrasive wear, delamination, and tribo-oxidation.

4. MANUFACTURING OF THE COMPOSITE

Among the various methods the stir casting method is one of the simple and best methods to create a uniform distribution of the reinforcement in the matrix composite based on surveys. In an electric induction resistance furnace, One kg of Al6061 alloy is melted in an electric furnace at 725˚C. The stirrer is rotated at 600 rpm up to 20 min so that the composite materials are well mixed. Then the combination of SiC and MoS_2 particles in equivalent volume fraction is added to the Aluminium molten metal. Before adding to Aluminium composite, these materials are preheated to 600˚C for an hour. The average diameter of the SiC and MoS_2 reinforcement particles is 24.5 lm. Now the combination of composite is poured into the permanent steel mould for obtaining the final composite material. The molten liquid composite is preheated around 250˚C and then allowed to solidify in an open atmosphere.

Fig. 1 Stir Casting Equipment

Fig. 2 Pure Aluminium Alloy



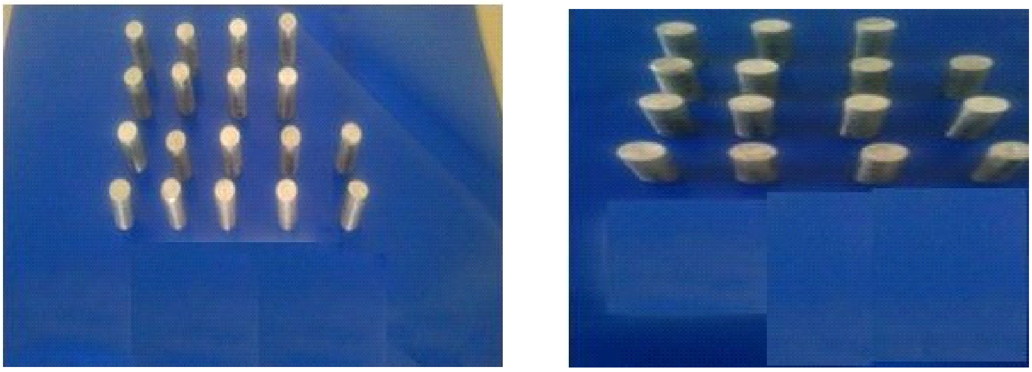
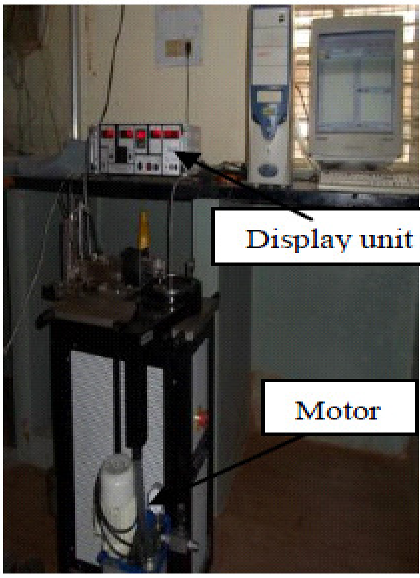


Fig. 3 Fabrication of Composites with Different Reinforcement



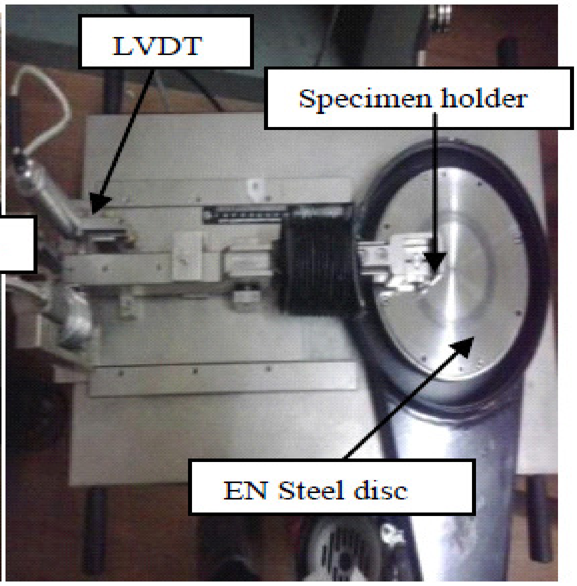


Fig. 4 Wear Tested Specimen **Fig. 5 Pin-on Disc Apparatus**

5. EXPERIMENT

The analysis of Aluminium Metal Matrix Composite reinforced with SiC-MoS_2 is conducted by stir casting process. All the experiments are conducted on a pin on disc wear testing machine at the foresaid condition.

6. RESULTS AND DISCUSSION

The experimental results are analyzed with the help of MINITAB14. The Table 1 shows the experimental results of Al-SiC-MoS_2 composite. The notations mentioned are factor A (% reinforcement), B (sliding speed), C (load), and D (sliding distance). The term BC is the interaction between sliding speed and load, BD is the interaction between the sliding speed and sliding distance, CD is the interaction between the load and sliding distance. From the experimental results, it could be seen that the sliding distance is the highest followed by sliding speed, load and % reinforcement of the composites. The effect of factors A, B, C and D are identical to that for Al-Sic-MoS_2 composite.

Table 1 Details of Test Combinations (TC) in Coded and Actual Values of Factors and Corresponding Experimental Results

Tc	A	B	C	D	%reinforcement	Speed	Load	Dist	Volume	Predicted
1	-1	-1	-1	-1	4	0.8	30	900	0.0081	0.0085
2	1	-1	-1	-1	8	0.8	30	900	0.0063	0.0068
3	-1	1	-1	-1	4	1.6	30	900	0.0041	0.0044
4	1	1	-1	-1	8	1.6	30	900	0.0026	0.0028
5	-1	-1	1	-1	4	0.8	30	900	0.0090	0.0093
6	1	-1	1	-1	8	0.8	60	900	0.0070	0.0074
7	-1	1	1	-1	4	1.6	60	900	0.0060	0.0063
8	1	1	1	-1	8	1.6	60	900	0.0049	0.0052
9	-1	-1	-1	1	4	0.8	40	1800	0.0165	0.0168
10	1	-1	-1	1	8	0.8	40	1800	0.0149	0.0152
11	-1	1	-1	1	4	1.6	40	1800	0.0098	0.0099
12	1	1	-1	1	8	1.6	40	1800	0.0085	0.0087
13	-1	-1	1	1	4	0.8	30	1800	0.0188	0.0189
14	1	-1	1	1	8	0.8	30	1800	0.0176	0.0179
15	-1	1	1	1	4	1.6	30	1800	0.0156	0.0157
16	1	1	1	1	8	1.6	60	1800	0.0134	0.0136
17	-2	0	0	0	0	1.2	60	1500	0.0119	0.0121
18	0	0	0	0	12	1.2	60	1500	0.0081	0.0083
19	0	-2	0	0	8	0.4	50	1500	0.0127	0.0128
20	0	2	0	0	8	2.0	20	1500	0.0078	0.0079
21	0	0	-2	0	8	1.2	20	1500	0.0055	0.0058
22	0	0	2	0	8	1.2	60	1500	0.0100	0.0098
23	0	0	0	-2	8	1.2	30	300	0.0020	0.0023
24	0	0	0	2	8	1.2	30	1800	0.0196	0.0194
25	0	0	0	0	8	1.2	30	1500	0.0087	0.0088
26	0	0	0	0	8	1.2	30	1500	0.0084	0.0087
27	0	0	0	0	8	1.2	30	1500	0.0089	0.0090

Table 2 ANOVA results of wear of Al-SiC-MoS_2

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	0.0000169	0.0000169	0.0000169	29.15	0.000
B	1	0.0000774	0.0000774	0.0000774	131.51	0.000
AB	1	0.0000000	0.0000000	0.0000000	0.03	0.873
C	1	0.0000381	0.0000381	0.0000381	65.12	0.000
AC	1	0.0000000	0.0000000	0.0000000	0.01	0.924
BC	1	0.0000046	0.0000046	0.0000046	7.31	0.021
D	1	0.0004359	0.0004359	0.0004359	740.84	0.000
AD	1	0.0000000	0.0000000	0.0000000	0.00	0.975
BD	1	0.0000033	0.0000033	0.0000033	6.25	0.025
CD	1	0.0000058	0.0000058	0.0000058	10.36	0.005
A*A	1	0.0000014	0.0000014	0.0000014	6.26	0.028
B*B	1	0.0000037	0.0000037	0.0000037	8.30	0.014
C*C	1	0.0000030	0.0000030	0.0000030	0.78	0.394
D*D	1	0.0000082	0.0000082	0.0000082	13.74	0.003
Error	12	0.0000071	0.0000073	0.0000007		
TOTAL	26	0.0006068				

7. CONCLUSION

The experiments are conducted on the composite with the reinforcement up to 8% Al-MoS_2 and Al-SiC composites using the pin–on-disc equipment. Based on the experimental results it could be seen that the mixed tribo layer has a great impact on the wear rate. Increase in speed resulting reduction of wear rate but there is an increase in wear rate with increase in load significantly. The wear rate of the composites is affected by the unstable tribo layer which increases with the sliding distance. In contrast, the increase in % reinforcement composition of the Al-SiC-MoS_2 composites resulting decrease in wear rate considerably.

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