An Experimental Study on Effect of Wear Properties of Aluminium Composite Reinforced With Silicon Carbide and graphide

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***1** Abstract*— Aluminium (Al) is the most plentiful element on earth and it became an economic competitor in the engineering applications at the end of the 19th century. The emergence of three important industrial revolutions would, by demanding material characteristics consistent with the same qualities of Aluminium and its alloys, greatly benefit growth in the production hybrid composite materials. Among the most striking characteristics is its versatility. Aluminium alloys and its composite materials are extensively used as the materials in transportation (aerospace and automobiles), engine components and structural applications.Thus it becomes all the more vital to study the tribological characteristics of Aluminium alloys and its composite materials. Addition of Silicon to Aluminium gives high strength to weight ratio, low thermal coefficient expansion, and high wear resistance. Hybrid Composite Materials show improved strength and wear properties as the silicon content is increased beyond composition. Such properties warrant the use of these materials as structural components in many industries [2]. Speed of disc & applied load has the higest influence on wear in microns. When the reinforcement increases wear in microns of composite material decreases. When the load increases wear in microns of composite material increases.

Key word: matrix, reinforcement, Aluminium SiC, Stair casting.

2. LITERATURE REVIEW:

K.K.Alaneme et.al.,[1] studied low cost – high performance Al matrix hybrid composites with the use of SiC and bamboo leaf ash as complementing reinforcements was investigated. The results show that the ultimate tensile strength, hardness, and % elongation of the hybrid composites decrease with increase in BLA content. The fracture toughness of the composites were however superior to that of the single reinforced Al 10wt% SiC composite. Only the 2 wt% bamboo leaf ash containing hybrid composite had specific strength value comparable to that of the single reinforced composite. In 5wt% sodium cloride solution, it was observed that the 2 and 3 wt % BLA containing hybrid composites had corrosion resistance in comparison between to the single reinforced Al - 10 wt% SiC composite but the reverse trend was observed in 0.3 M H2SO4 solution where the single reinforced had superior corrosion resistance.

S. cemokumus et.al., [2] Studied Aluminum-silicon based hybrid composites reinforced with SiC and graphite particles were prepared by liquid phase particle mixing and squeeze casting. The thermal conductivity and thermal expansion behaviors of composites with various graphite contents (5.0; 7.5; 10 wt.%) and different SiC particle sizes (45 µm and 53 µm) were investigated.

M.Sreenivasa Reddy et.al .,[3] Metal Matrix Composites (MMCs) constitute an important class of weight-efficient and design structural materials that are encouraging every engineering applications and mainly in aerospace applications. The MMC is manufactured for the different compositions of E-glass and Graphite particulates. The results are recorded and it is resulted that the MMC obtained has got better tensile strength compared to Aluminum alloy alone. Further, the tensile strength slightly increased with 1 hour aging heat treatment.

Prabhakar Kammeret.al., [4] studied on Conventional monolithic materials have limitations in achieving good combination of stiffness, strength, toughness and density. Metal matrix composites possess significantly improved properties including high specific strength; damping capacity, specific modulus, and wear resistance compared to unreinforced alloys. Among the MMC's aluminum composites are predominant in use due to their high strength and low weight. The key features of MMC's are specific strength and stiffness, excellent high thermal wear resistance, high thermal and electrical conductivity. The present investigation aims at the development of Aluminium based E-Glass and Graphite particulate reinforced hybrid metal matrix composites. The prepared test specimens are as per ASTM standard size by facing and turning operations to conduct tensile and compression test.

From the literature review it is observed that, many researchers have done research on Hybrid composite and they have successfully casted Material at different % of reinforcement material. They have experimentally investigated and characterized the different test. They found that different Mechanical and wear properties of Hybrid composites are enhancing with increasing % of reinforcement.

3. Wear Behaviour

A pin on disc test instrument was prepare to determine the sliding wear characteristics of the composite. The size of Specimens are 10 mm diameter and 30 mm length were cut from the samples, machined and then polished. The contact surface of the cast sample (pin) has to be in contact with the rotating disk. During the test, the pin is held pressed against a rotating steel disc (hardness of 65HRC) by applying load that acts as counterweight and balances the pin. The track radius was varied for each batch of experiments in the range of 70 mm - 110 mm and the parameters such as the load, sliding distance and sliding speed were varied in the range given in Table 3.1. A LVDT (load cell) on the lever arm helps determine the wear rate at any point of time by monitoring the movement of the arm. The surface in contact with rotating disc wears out, the load pushes the arm to remain in contact with the disc. This movement of the arm produce a signal which is used to determine the maximum wear rate and the coefficient of friction is monitored continuously as wear occurs.Weight loss of each specimen was obtained by weighing the specimen before and after the experiment by a single pan electronic weighing instrument with an accuracy of 0.0001g after thorough cleaning with acetone solution.

Table 3.1 Process parameters and levels

Level	Load ,L (N)	Sliding speed, S (m/s)	Sliding distance,D(m)
1	20	1.5	700
2	30	2.5	1400
3	40	3.5	2100

4. PLAN OF EXPERIMENTS

Dry sliding wear test was performed with 3(THREE) parameters: applied load, sliding speed, and sliding distance and varying them for 3 (three) levels. According to the rule that DOF(degree of freedom) for an orthogonal array should be greater than or equal to sum of those wear test parameters, a L27 Orthogonal array which has 27 rows and 6 columns was selected as shown in Table . The selection of Orthogonal array depends on 3 (three) items in order of priority, viz., the number of factors and their number of levels, interactions for the factors and the desired experimental resolution or cost limitations. A total of 27(twenty-seven) experiments were performed based on the run order generated by the Taguchi model. The response for the model is coefficient of friction and wear rate. In Orthogonal array, second (2^{nd}) column is assigned to applied load, the third (3^{rd}) column is assigned to Sliding speed and fourth (4^{th}) column is assigned to sliding distance and the remaining columns are assigned to their interactions. The objective of model is to minimize coefficient of friction and wear rate. The responses were tabulated and results were subjected to Analysis of Variance (ANOVA). The Signal to Noise (S/N) ratio, which condenses the multiple data points within a trial, depends on the type of characteristic being evaluated. The S/N ratio characteristics can be divided into 3 (three) categories, viz. 'nominal is the best', 'larger the better' and 'smaller the better 'characteristics. In this study, 'smaller the better' characteristics was chosen to analyse the dry sliding wear resistance.

5. Results of Statistical Analysis of Experiments

The results for various combinations (mixed) of parameters were obtained (determined) by conducting the experiment as per the Orthogonal array. The determined results were analysed using the commercial software MINITAB 14 specifically used for design of experiment applications. Table 6.1 shows the experimental results average of two repetitions for coefficient of friction and wear rate.

To measure the quality characteristics (properties), the experimental values are transformed into signal to noise ratio. The influence of control parameters such as sliding speed, sliding distance, load and load on coefficient of friction and wear rate has been analysed (comparing) using signal to noise response table. The ranking of process parameters using signal to noise ratios obtained for different parameter levels for wear rate and coefficient of friction are given in Table 6.1. The control factors are statistically significant in the signal to noise ratio and it could be observed that the sliding distance is a dominant parameter on the wear rate and coefficient of friction followed by sliding speed and applied load and. Figure (6.1-6.2) shows the influence of process parameters on wear rate and coefficient of friction graphically. The analysis (compared) of these experimental results using S/N gives the optimum conditions resulting in minimum wear rate and coefficient of friction. The optimum condition for coefficient of friction and wear rate as shown in Figure 6.1 and 6.2 are L1, S3 and R3.Thus, the optimal setting of control factors for better wear resistance of hybrid metal matrix composite were arrived at.

6. Analysis of Variance Results for Wear Test

The experimental results were analysed (compaired) with Analysis of Variance (ANOVA) which is used to investigate the influence of the considered wear parameters namely, applied load, sliding distance and sliding speed, and that significantly affect the performance measures. By performing analysis of variance, it can be decided (find) which independent factor dominates over the other and the % contribution of that particular independent variable. Table 6.2 and 6.3 show the ANOVA results for coefficient of friction and wear rate for three (3) factors varied at three (3) levels and interactions of those factors. This analysis is carried out for a significance level of α=0.051, i.e. for a confidence level of 95%. Sources with a P-value less than 0.05 were considered to have a statistically significant contribution to the performance measures. In Table 6.2 and 6.3, the last column shows the % contribution (Pr) of each parameter (level) on the total variation indicating their degree of influence on the result. increases from 20 N to 40N Load. In second graph shows that

that the sliding speed (S) in m/s increases the wear rate is going to decreases . Third graph shows that when sliding distance is increases the wear rate of composite material is decreasing

Table 6.1 Orthogonal array and results of HMMC.

Exp .No .	L(N)	S(m/s)	D(m)	Coefficient of friction	Wear rate (mm³/m)
1	20	1.5	700	0.377	0.003653
2	20	1.5	1400	0.330	0.00344
3	20	1.5	2100	0.312	0.002045
4	20	2.5	700	0.341	0.003018
5	20	2.5	1400	0.335	0.002245
6	20	2.5	2100	0.31	0.001945
7	20	3.5	700	0.355	0.002868
8	20	3.5	1400	0.324	0.001938
9	20	3.5	2100	0.306	0.001808
10	30	1.5	700	0.386	0.004074
11	30	1.5	1400	0.356	0.003141
12	30	1.5	2100	0.322	0.002493
13	30	2.5.	700	0.372	0.003092
14	30	2.5	1400	0.347	0.002468
15	30	2.5	2100	0.321	0.0023
16	30	3.5	700	0.343	0.002905
17	30	3.5	1400	0.334	0.002356
18	30	3.5	2100	0.318	0.002189
19	40	1.5	700	0.419	0.005
20	40	1.5	1400	0.37	0.003962
21	40	1.5	2100	0.361	0.002905
22	40	2.5.	700	0.402	0.004439
23	40	2.5	1400	0.364	0.00345
24	40	2.5	2100	0.355	0.002661
25	40	3.5	700	0.389	0.004214
26	40	3.5	1400	0.353	0.003292
27	40	3.5	2100	0.343	0.002692

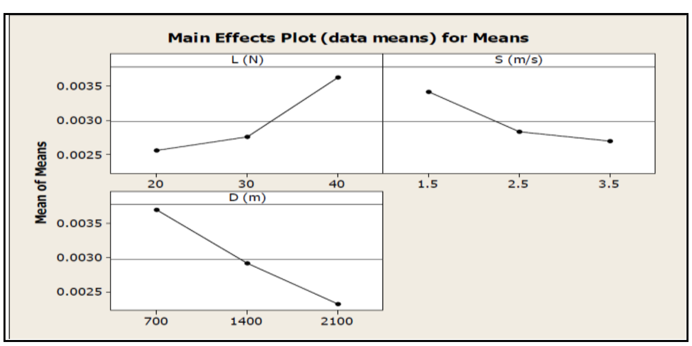

Fig. 6.1 Main Effects plot for Means -Wear rate

It can be observed from Fig 6.1, Load on the Pin (composite material) increases the wear rate of the composite material.

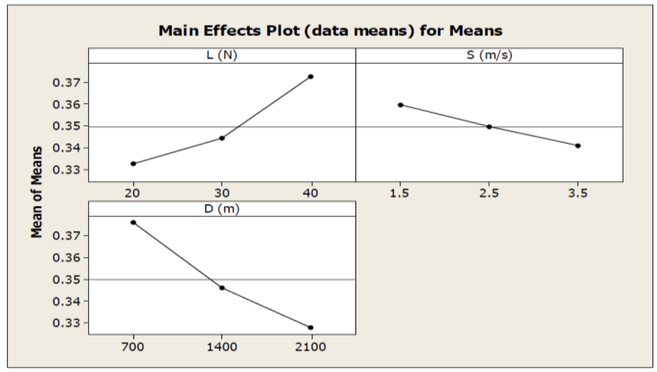

Fig. 6.2 Main Effects plot for Means –coefficient of friction

It can be observed from Fig 6.2, Load on the Pin (composite material) increases the coefficient of friction of the composite material increases from 20 N to 40N Load. In second graph shows that that the sliding speed (S) m/s increases the coefficient of friction is going to decreases. Third graph shows that when sliding distance is increases the wear rate of composite material is decreasing.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Pr (%)
L (N)	2	0.0000058	0.0000058	0.0000029	99.56	0.000	31.5
S (m/s)	2	0.0000026	0.0000026	0.0000013	45.02	0.000	14.1
D (m)	2	0.0000086	0.0000086	0.0000043	147.55	0.000	46.8
L(N)*S(m/s)	4	0.0000001	0.0000001	0.0000000	0.72	0.604	0.5
L(N)*D(m)	4	0.0000004	0.0000004	0.0000001	3.66	0.056	2.2
S(m/s)*D(m)	4	0.0000005	0.0000005	0.0000001	4.54	0.033	2.7
Error	8	0.0000004	0.0000004	0.0000000			2.2
Total	26	0.0000184					100

Table 6.2 Analysis of Variance for wear rate (mm³/m)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Pr (%)
L (N)	2	0.0076750	0.0076750	0.0038375	73.24	0.000	35.7
S (m/s)	2	0.0015692	0.0015692	0.0007846	14.97	0.002	7.3
D (m)	2	0.0107612	0.0107612	0.0053806	102.69	0.000	50.0
L(N)*S(m/s)	4	0.0002093	0.0002093	0.0000523	1.00	0.462	1.0
L(N)*D(m)	4	0.0003453	0.0003453	0.0000863	1.65	0.254	1.6
S(m/s)*D(m)	4	0.0005344	0.0005344	0.0001336	2.55	0.121	2.5
Error	8	0.0004192	0.0004192	0.0000524			1.9
Total	26	0.0215134					100

Table 6.3 Analysis of Variance for coefficient of friction

It can be observed from the Table 6.1, that the sliding distance has the highest influence (P=46.8%) on wear rate. Hence the sliding distance is an important control factor (K) to be taken into consideration during wear process followed by applied load (P=31.49%) and sliding speed (14.1%). Among the interaction terms, interaction between and distance sliding speed alone have significant influence (P=2.71%) on wear rate of the Hybrid metal matrix composite (HMMCs). Other interaction are above the confidence level of 0.051, therefore those interactions can be neglected. The pooled error is low, accounting for only 2.2%. In the same way from Table 5.4 for coefficient of friction, it can be observed that the sliding distance has the highest contribution of about 50%, followed by applied load (P=35.7%) and sliding speed (P=7.31%).The interaction terms has little or no effect on coefficient of friction and the pooled errors accounts only 1.9%. From the analysis of variance and S/N ratio, it is inferred that the sliding distance has the highest contribution on coefficient of friction and wear rate followed by load and sliding speed.

7. Multiple Linear Regression Models

A multiple linear regression model is developed (produced) using statistical software "**MINITAB R14**". This model gives the relationship between an independent or predictor variable and a response variable by fitting a linear equation to observed data. Regression equation thus generated establishes correlation between the significant terms obtained from ANOVA analysis, namely, sliding speed, applied load, sliding distance and their interactions. The regression equation developed for wear rate is

Wr = 0.00446 + 0.000055 L - 0.000690 S - 0.000002 D + 0.0000001 S*D Eq(A)

The regression equation developed for coefficient of friction is

Cf = 0.361 + 0.00202 L - 0.00933 S - 0.000035 D Eq(B)

From Eq(A) and Eq(B), it is observed that the sliding speed plays a major role on coefficient of friction and wear rate followed by sliding distance and applied load. So the important factor affecting the dry sliding wear behaviour is sliding speed. It can also be inferred from the Eq(A) and Eq(B), that the negative value of the co-efficient of speed reveals that increase in sliding speed decreases the coefficient of friction and wear rate. This can be attributed to the oxidation of aluminium alloy, which forms an oxide layer at higher interfacial temperature thus preventing the sliding, thereby by decreasing the coefficient of friction and wear rate and a similar behaviour has been observed. It was also reported that, iron was oxidized during wearing process and has been shown that oxide layers, in particular iron layers generated during wear, act as solid lubricants and help to reduce the wear rates. In the case of Al 2219/SiC/Gr, as sliding speed increases, the wear rate decreases up to 4.52 m/s, the silicon carbid (SiC) in the hybrid composites wear the counter face and iron oxides were formed by oxidation of iron particles from the counter face. Thus the formation of stable oxide films can reduce friction and retain such oxide films on the surface.

CONCLUSION:

The conclusions drawn from the present investigation are as follows:

Following are the conclusions drawn from the study on dry sliding wear test using Taguchi's Technique.

- Sliding distance (46.9%) has the highest influence on wear rate followed by sliding speed (14.1%) and applied load (31.5%) and for coefficient of friction, the contribution of sliding distance is 50%, sliding speed is 7.3% and applied load is 35.7%
- Incorporation of graphite as primary reinforcement increases the wear resistance of composites by forming a protective layer between counter face and pin and the inclusion of SiC as a secondary reinforcement also has a significant effect on the wear behaviour.
- Regression equation generated for the present model was used to predict the wear rate and coefficient of friction of Hybrid Metal Matrix Composite for intermediate conditions with reasonable accuracy.

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