Optimization and tribological properties of A380 alloy with hybrid composites

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Abstract: **In this experimental work, the A380 was refined with a mixture of graphite particles and fly ash using a stir casting technique. Fly ash particles made from NTR thermal power plant, combined with self-lubricating graphite particles. The reinforcement is mixed in various proportions with 2% by weight of A380 alloy. % Graphite and 2-4% by weight. % Fly ash dust particles. After bonding the base and the hybrid alloy, the wear during the dry creep test is calculated. Dry sliding wear test at various loads of 5N, 10N and 15N, sliding times 15, 30 and 45 minutes with a disk diameter of 60 mm. Various methods such as Taguchi and ANOVA are used to study the effect of wear parameters on friction. In addition, the lowest value was selected with the status functions of the MINITAB-18 program.**

Keywords: **A380 alloy, Fly ash, Graphite, stir Casting, ANOVA, MINITAB-18.**

I.INTRODUCTION

Composite material is one of the reliable solutions to this problem. In composite materials, materials are assembled so that they can make better use of their original material while minimizing the impact of their defects. Aluminum matrix composites (AMCs) are potential applications due to materials with good physical and mechanical properties. The addition of reinforcement to the metal matrix improves the properties of stiffness, resistivity, wear, creep and fatigue over specific engineering materials. In recent decades, compounds with a metal matrix based on aluminum alloys have played an important role in various technical applications [1]. AMC are new advanced binary phase composites; H. Aluminum matrix and reinforcement, such as graphite, Al_2O_3, TiC, SiC, B_4C, are rigid reinforcing elements for the production of composite materials [2]. At best, metallic aluminum is chemically precisely matched to ceramic reinforcement and bond shapes to improve general properties such as workability, specific strength, fatigue, thermal conductivity, stiffness, wear resistance and corrosion. The improved properties show that AMMC's aluminum-metal matrix composites play an important role in a variety of applications such as automotive cylindrical parts, pistons, brakes, cylinder liners, connecting rods and many energy generating elements.

Friction wear at various critical parameters and hybrid metal matrix composites that affect friction and wear, such as sliding path, percentage of reinforcement and applied load, have been studied by many other people [3-6]. Many other authors have used analysis of variance (ANOVA) and Taguchi methods to find important parameters that influence friction and wear. A. Baradeswaran et al. observed that the wear characteristics of the A7075 / graphite / Al_2O_3 hybrid composites overlap the coefficient of friction of the A7075 alloy, which is reduced by 5% by weight. % Addition of graphite and up to 8% by weight of Al_2O_3[7]. The friction coefficient of graphite particles mixed with pure aluminum reaches 5% by weight. % and then decreases to increase the scrolling speed. The sliding distance is described by S. Rajesh et al. [8] reported. Various studies have concluded that process / wear parameters affect wear / different coefficients of friction in the AMMC field.

The change in wear parameters is not heterogeneous for each combination of friction and wear. In this experimental work, wear and friction of basic Al-Si alloys, to which were added granite dust and graphite particles, were studied in various fields using ANOVA and Taguchi methods [9-15].

II. LITERATURE SURVEY

Shashi Prakash Dvivedi et al. (2014) in this report, the author investigated the electromagnetic mixing process of A380/SiC compounds. In this study, an A380/SiC metal matrix compound with various percentages of reinforcement by weight (5%, 10% and 15%) was formed by electromagnetic agitation and showed a significant improvement in its mechanical properties such as uniformity of the microstructure, fatigue, etc.

Dinaharan et al. (2016) The paper describes various properties of fly ash, enhanced by AMC and obtained by friction stir molding, for example: B. light microscopy, scanning electron microscopy and electron backscatter diagram. In AMC we observe a homogeneous AF, created by the hardness that moves the friction. The result obtained from the composite material showed a significant increase in micro hardness and wear resistance.

Ezatpur researchers, H. R. et al. (2013) studied various mechanical properties such as hardness, performance stability, maximum tensile strength with a mass fraction of Al_2O_3 in aluminum. The composite material was made by shaking. In this process, the author also reported on various parameters such as rotational speed, injection time, speed, etc., which were taken into account during the mixing process.

Anilkumar et al. (2013), this paper investigates the mechanical and tribological properties of the AMC compound, which are enhanced by changing the particle size of the fly ash. Three sets of composite material with 75-100 micron fly ash particles were made. m, 45 to 50 µm m and 4 to 25 µm m and a comparative study was performed with aluminum. The result showed a significant decrease in mechanical properties such as compressive strength, tensile strength and hardness, as the size of fly ash particles in AMC blends increased with uniform fly ash distribution.

Grigorios Itskocet et al. (2011) In this report, Al-Fly A380 ash compounds were synthesized by pressure infiltration using Class C (MMC) (C) metal matrix compounds, which have an excellent combination of physical, mechanical and tribological properties and their application is still limited due to the high production costs. Fly ash was separated into different sized fractions by manual sieving using appropriate screens. Finally, it has been said that small particles of fly ash can take advantage of the properties of the compounds and that grinding the fly ash facilitates the production of MMC through pressure infiltration and also benefits from its abrasive properties.

III. METHODS AND MATERIALS

In this dissertation, hybrid metal matrix aluminum composites, which contain particles of graphite and fly ash, are obtained from fly ash from a thermal power plant. The chemical composition of the obtained fly ash particle sample is shown in Table 1 below. The graphite crucible is removed and filled with 500g of fly ash particles. The granite is then preheated to 850 ° C for 4 hours to determine the ignition loss in the muffle furnace. After cooling, the granite particles, preheated to room temperature, were purified with distilled water to remove impurities and remove moisture from the granite at 120° C for 48 hours. The fly ash particles then change color from gray to brick. The dried fly ash dust was filtered for 30 minutes using a stirrer with a BSS mesh size of 100 to 350. The results show that more than 70% of the average 53 µm particle size remained at -200 + 350 mesh, therefore the reinforcement was chosen synthesis of hybrid composites of this size. The matrix material of alloy A380, the chemical composition of which was selected for this work, is presented in Table 2.

A muffle furnace was used to melt the base Al-Si alloy and its composites, which were placed in a graphite crucible. The position of the stirring jet is shown in Fig. 1 (a). After reaching the correct temperature i. H (700° C) a vortex was formed. The preheated graphite particles and fly ash powder were rolled into a liquid aluminum phase with varying weight fluctuations of 2 wt% graphite and 2 wt%. % Fly Ash In the main case, again, the weight percentage of fly ash increased to 4% by weight. % Preservation of permanent graphite reinforcement. To ensure a continuous and even flow of the reinforcement mixture, a conical GI sheet is used so that the reinforcement of the mixture precisely adds the swirl. For comparison, the pure graphite particles were strengthened without the addition of granite dust. Argon gas is passed around the melt to prevent oxidation. The mold for making composite pins is made of gray cast iron as shown in fig. 1 (b).

Fig. 1(a) Setup for Casting (b) Fabrication of Fingers in Grey Cast Iron Die

Specimen Preparation for Wear

Dry sliding wear test is carried on a wear testing machine (Ducom TR- 20 LE: Model) shown in Fig. 2, sliding a cylinder-shaped sample opposing the surface of the hard steel (HS) disc (HRC 62) under room temperature conditions. Maintain a smooth surface of the disc for each and every new test. The wear test specimens were shown in Fig. 3. By using

Table 1 Fly Ash Particles Chemical Compositions

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Ignition loss
58.41	30.40	8.44	2.75	1.3	1.53	1.0	1.98	2.4

Table 2 A380 Alloy Chemical Compositions

Constituent	Si	Zinc	Ni	Fe	Cu	Al
wt. %	7.5-9.5	3.0	0.50	1.3	3.40	balance

Table 3 Levels And Their Parameters

Levels	Loads(L) (N)	Time(T) (min)	Reinforcements(R) (Wt.%)
1	5	15	Base alloy A380
2	10	30	2% Graphite
3	15	45	2% Gaphite+4% Fly-ash

wire cut EDM, Both composite and alloy specimens are prepared with the dimension of 4 mm X 40 mm diameter (ASTM G99 Standard). Before testing, test samples were polished with emery paper and apply acetone and then dried in room temperature.

Fig. 2 Ducom TR- 20 LE with Controllers Fig. 3 Wear Test Specimens

Conducting of Dry Sliding Wear

Three parameters and three levels were considered to conduct the wear test of dry sliding. Reinforcement, sliding time, and load are the three individual parameters considered in this work. Process parameters are second and third and material dependent parameter is the remaining one. Table 3 shows the parameters which are chosen for this experiment with their levels. Track diameter of 60mm with 640 rpm was selected to conduct test for wear specimens.

Experimental Values of Wear Test

Frictional wear parameters with different combinations are such as sliding time and reinforcement percentage of load are gathered as per orthogonal array L_{27}. Investigational parameters of each set is considered from three trails of mean value of wear is shown in Table 4. Wear rate is effected by several parameters/factors. Obtained from the various authors and reviewers, it is resulted that the applied load, sliding time and reinforcement weight % are the most important process parameters/factors. The pin-on-disc data for different test conditions planned as per L_{27} orthogonal array are plotted in the following graphs/figures.

Composite Microstructures Results and Discussion

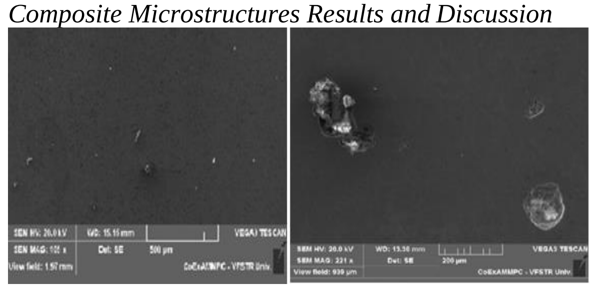

Fig. 4(a) SEM Image of A380 Base Alloy (b) A380 Base Alloy with Fly ash Dust and Graphite Reinforcement

A380 base alloy SEM microstructure is a silicon needle shaped primary structures was established its interdendritic boundaries as shown in Fig. 4(a) and clearly observed that spreading of the granite dust particles in the composition is shown in Fig. 4(b) shown that the uniform distribution of both graphite and fly ash particles in microstructure.

IV.RESULTS AND DISCUSSION

The results for wear in different ratios of reinforcement are obtained as per orthogonal L_{27} array. By using statistical software "MINITAB 18" in three phases measured wear results are analyzed.

1) Each process factor of effecting wear is calculated to find out the rank by using Signal-to-Noise (S/N) Ratio

2) Each process factor effecting wear was analysed with ANOVA to know the percentage of contribution

3) To find out the relation between wear with applied load, reinforcement of graphite and granite dust, Sliding time developed the mathematical model.

4) To estimate the coefficient of friction 2D contour plots are drawn with reference to any two sliding parameters or with reference to any two process parameters.

Signal to Noise Ratio(S/N) Results

By using S/N ratio convert the experiment results which are obtained, smaller is better response with objective function of wear. With the help of applied load, sliding time and the weight percentage of reinforcement have been analyzed with wear parameters. Each trail of three tests are calculated as mean value and wear rate of S/N ratios composites are mentioned in the Table 5. S/N ratio of highest process parameters would give the minimum variance with optimum quality. The equation (1) for 'small value is best' quality characteristic is,

$S/N_{SM=}$ $-10 \times \log (\Sigma (Y^2) /r)$ ------------------------(1)

Table 4 Comparisons of Wear (Measured In Micrometer) Results

	A380 Alloy			2 wt.% Graphite			2% wt. Graphite and 4% Fly-ash Dust		
Load(N)	15min	30min	45min	15min	30min	45min	15min	30min	45min
5	102	281	731	79	247	439	49	77	147
10	330	561	841	251	469	687	173	382	438
15	593	1125	1211	508	759	989	408	589	659

Result Analysis S/N Ratio

Table 5 Process Factors Of S/N Ratio

S.No	Applied load (N)	Reinforcements (wt %)	Time (min)	Wear (μm)	SNR for Wear
1	5	0	15	102	-40.172
2	5	0	30	281	-48.974
3	5	0	45	731	-57.278
4	5	2	15	79	-37.952
5	5	2	30	247	-47.853
6	5	2	45	439	-52.849
7	5	2+4	15	49	-33.803
8	5	2+4	30	77	-37.729
9	5	2+4	45	147	-43.346
10	10	0	15	330	-50.370
11	10	0	30	561	-54.979
12	10	0	45	841	-58.495
13	10	2	15	251	-47.993
14	10	2	30	469	-53.429
15	10	2	45	687	-56.739
16	10	2+4	15	173	-44.760
17	10	2+4	30	382	-51.641
18	10	2+4	45	438	-52.829
19	15	0	15	593	-55.461
20	15	0	30	1125	-61.023
21	15	0	45	1211	-61.389
22	15	2	15	508	-54.117

23	15	2	30	759	-57.608
24	15	2	45	989	-59.903
25	15	2+4	15	408	-52.213
26	15	2+4	30	589	-55.402
27	15	2+4	45	689	-56.764

Control factor influence the S/N ratio reaction table of wear studies. S/N ratio and average wear gives the perfect ranking of process factors which are evaluated from the Table 6 and Table 7. it is concluded from the ranking i.e applied load is the highest effect contributes the wear parameters back after sliding time and percentage of reinforcement.

Table 6

Response For Mean Wear (Smaller Value Is Best)

Levels	Applied Load(L) Kgf	Reinforcements (R)Wt. %	Sliding Time(T) min
1	230.6	658	271.4
2	472.8	441.3	485.8
3	731.5	310.3	676.8
Delta	500.9	347.6	405.4
Ranking	1	3	2

Table 7

Signal-To-Noise Ratios Wear Responce (Smaller Value Is Best)

Levels	Applied Loads(L) kgf	Reinforcements (R) Wt. %	Sliding Time (T) min
1	-44.10	-55.89	-46.33
2	-53.67	-52.73	-52.59
3	-58.18	-47.21	-56.83
Delta	14.07	8.68	10.50
Ranking	1	3	2

Effect of Parameters on the Wear

Plot the main effect of wear friction which is independent of each parameter on the effect of outcomes as shown in Fig. 5 and Fig. 6 plots the mean effect of S/N ratio again it is independent of all parameters on the outcomes. Raising line of the main effecting plot shows how the effect of wear in each process factor. High slope means large is the effect of load is the main effect factor back after sliding time and the reinforcement percentage.

The residual plot is derived from "MINITAB18" programming, it explains more about its tendency and consistency of experimental data. The residuals are more clearly concentrated at lower errors. Normal probability plot for error bar is shows that proportion of data closer to the central valves. Fig. 7 itself indicates the results calculated from the data analysis are valid.

Reinforcement and Effect of Load on Wear Friction: Load increase wear rate is also increases. Graphite and granite dust particles were comes out from the composite throughout wear dry sliding and SiO_2 layer there in thermal power plant dust over the surface of the contact which is effected by the temperature. If the load is increase from 5N to 15N layer came out partially hard silicon layer which is oxidized, groves and scratches can be observed on the surface of the specimen pin. The wear friction was reduced with increase in reinforcement because of the presence of self-lubricant thin layer mixed on the surface. In the presence of tiny industry dust particles which are came out from the composite was greater. So it results as wear volume was increased.

P. Ravindran et al. [16], studies Al hybrid composites of wear with graphite particles, developed the linear regression mathematical model for wear as its function of graphite weight percentage, speed, sliding distance and load effectiveness of the normal probability plots of the residuals are compared with mathematical model. The normal probability line is very closer to the points. A so mathematical model that is concluded its effectiveness. P. Shanmughasundaram Palanisamy [17] was improved Al-Alloy 7075 reinforced with Al_2O_3 mathematical equation for wear for a purpose of velocity particle size, sliding and load. So that it explains the loss of volume in wear composites, increases with increasing load and sliding velocity, if particle size increase wear resistance of composite is also increases.

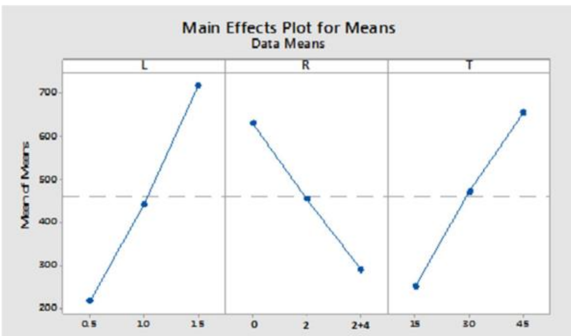

Fig. 5 Mean Wear of Main effects plot

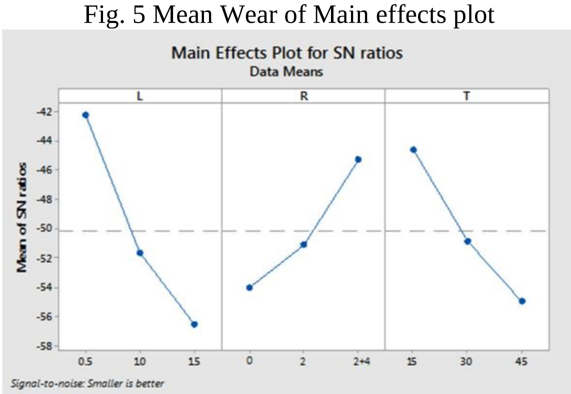

Fig. 6 S/N Ratio of Wear Main Effect's Plot

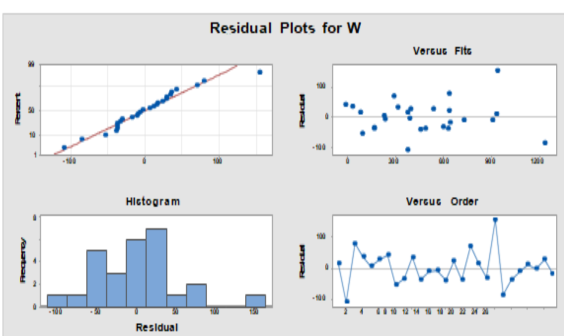

Fig. 7 Error Bars for Wear from Taguchi (W=Wear)

Analysis of Variance Method

To examine the percentage of effect factor on outcome of wear is used by Analysis of Variance (ANOVA). Analysis of Variance is worked with the help of "MINITAB18" software package for a level of significance of 2% (it indicates 95% confidence levels). Table 8 shows the obtained results. ANOVA analysis itself conclude all the three elements have effect the composite on wear. Table 8 of column 6 mentions contribution (p) of each element on the total variation on wear and it shows that three elements (L,R,T) having zero wear effects on variation in the outcome. By considering independently all the elements are important. However the interactional elements have some effects on wear difference in the evaluation. The interactional influence of L*R is 95% is not important at the confidence level. Some other interactional element like L*T and R*T are important to a certain levels

It is identified from the last column of the Table 8 is for the dry sliding wear teat of composite, load is the most important parameter is having the (42.73%) highest percentage contributed sliding time (27.47%) is coming after the load and finally (22.20%) of reinforcement. So consider that load is the main control element should take during the wear sliding test followed by sliding time and reinforcement (percentage of weight) graphite and granite dust. Table 9 shows that R-square value is higher than 95%. Hence it is verified that results are more important.

The Parameters of wear Normal Plot Analysis

Normal plot of different parameters are shown in Fig. 7. Brown colored rectangles are indicated as important terms. However blue colored circles are mentioned as not important terms. The left side term R is the normal plot indicates, that the reduction of contribute in wear up to its increase. Remaining L and T terms on the right side top of normal plot and it explains that wear increases until its increase.

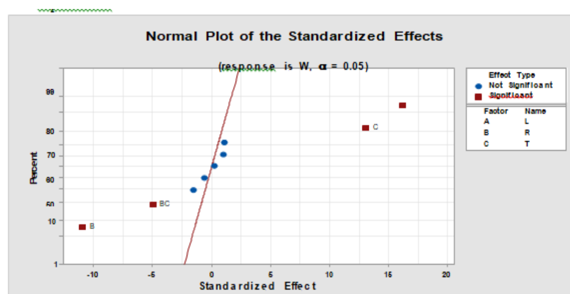

Fig. 7 Standardized Effect of the Normal Plot for Wear in RSM Model (Full Quadratic Form)

Table 8 . Anova for Wear

Elements	DoF	Sum of Squares	Mean Square	F-value	P-value	% of Contribution
L	2	1137486	568743	121.1	0	43.63
R	2	521746	260873	55.89	0	21.10
T	2	738939	369470	79.81	0	26.57
L*R	4	15165	3791	0.82	0.618	0.78
L*T	4	32897	8224	1.68	0.249	1.07
R*T	4	111019	27755	6.02	0.018	5.18
Error	8	37885	4736	_	_	1.46
Total	26	2595138	_	_	_	100

Table 9 Model Brief Summaries

S	R-sq	R-sq(adj)
69.35	97.87%	94.92%

V.CONCLUSION

Dry sliding wear behavior is done on wear test for hybrid aluminium metal matrix composites at room temperature for the above methods, results and discussions are the following conclusion

A. Hybrid composites increase the wear resistance by adding fly ash and graphite particles to Al-Si alloy metal matrix. Also if load increases wear of the selected hybrid composite is also increasing and at higher sliding time.

B. SEM images of A380 base alloy with reinforcements of graphite and fly ash dust particles are verified and found that clear distribution of particles in the composition.

C. By using force sensors loads can be applied to calculate the sliding distance and wear in between the steel disc and composite alloy pin.

D. The results indicated that load is the main important parameter of S/N ratio came after the sliding time and reinforcement added.

ANOVA results shows that 43.63% of applied load on wear is the major contributing element came after 26.57% of sliding time and reinforcement of granite and graphite of 21.10% on wear in the present studying of hybrid composites.

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