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An Investigational Analysis of the Wear Parameters in the Friction Performance of the A356 Alloy with Hybrid Compounds

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Abstract: In this experimental work, Al-Si (A356) was improved with a mixture of graphite particles and fly ash using the stirring casting technique.

Dust particles from fly ash obtained from the NTR thermal power plant during use in combination with graphite particles that have self-lubricating properties. The reinforcement is mixed in various proportions with the A356 alloy with 2% by weight. % graphite and 2-4% by weight. % fly ash dust particles.

After making the basic and hybrid alloy connections, wear is calculated during the dry slip test. Dry slip wear test of different loads 5N, 10N and 15N, sliding time of 15 minutes, 30 minutes and 45 minutes respectively with a disc diameter of 60 mm. To study the effect of wear parameters on friction, various techniques are used such as Taguchi and ANOVA. In addition, the smallest value was selected using the "MINITAB18" program status functions.

Keywords: A356 alloy, Fly ash, Graphite, stir Casting, ANOVA, MINITAB 18.

I. INTRODUCTION

The composite material is one of the reliable solutions for this need. In composite materials, the materials are joined in such a way as to allow us to make better use of their original material and, at the same time, minimize the effects of their deficiencies. Aluminum matrix composite materials (AMC) are potential applications due to materials with good body and mechanical properties. The addition of reinforcements in the metal matrix improves the properties of rigidity, specific strength, wear, creep and fatigue compared to specific technical materials. In recent decades, aluminum alloy based metal matrix compounds are playing an important role in various engineering applications [1].

AMC's are recently advanced composite materials which made up of binary phases i.e. aluminium matrix and the reinforcement, example graphite, Al_2O_3, TiC, SiC, B_4C are hard reinforcements to manufacture composite materials [2]. Maximum the aluminium metal is chemically in conformity with the ceramic reinforcements and bonding forms exactly, hence that the general characteristics like workability specific strength, fatigue, thermal conductivity, stiffness, wear resistance, and corrosion will be enhanced. Improve properties shows that aluminium metal matrix composites AMMC's act as an important role in different applications like cylinder vehicle parts, piston, brakes, cylinder liners, connecting rod and so many power generated elements.

The frictional wear carrying out of various crucial parameters and hybrid metal matrix composites which effect the friction and wear like sliding distance, reinforcement percentage and applied load was studied by many other persons [3-6]. Analysis of variance (ANOVA) method and taguchi techniques was utilized by so many other authors to find out the important effecting parameters on friction and wear.

A. Baradeswaran et al. observed that A7075/graphite/Al_2O_3 hybrid composites wear behavior and covered the coefficient of friction of A7075 alloy reduced with 5 wt. % adding of graphite and up to 8 wt. % of adding Al_2O_3 [7]. The coefficient of friction of graphite particles mixed in pure aluminium up to 5 wt. % and then reduced with improving in sliding velocity. Sliding distances is reported by S. Rajesh et al [8]. In different studies it has been concluded that, the process/wear parameters influencing wear/various field coefficient of friction of AMMC's.

To concerning replacement of wear parameters are not an inhomogeneous pattern for each and every composite of friction and wear. In this experimental work, the wear and friction behaviors of Al-Si base alloy added with granite dust and graphite particles was studied by ANOVA and taguchi methods at various field [9-15].

II.LITERATURE SURVEY

Shashi Prakash Dwivedi et.al. (2014) in this report, the author studied the electromagnetic agitation process of the A356 / SiC compounds. In this survey, the metal matrix compound A356 / SiC with different weight percentages of reinforcements (5%, 10% and 15%) was formed by electromagnetic agitation and showed a significant increase in its mechanical properties, such as homogeneity of microstructure, fatigue, etc. Dinaharan et.al. (2016) The document reveals the various characteristics of fly ash reinforced with AMC produced by the stirring friction molding process, such as optical microscopy, scanning electron microscopy and the electronic backscatter diagram. Homogeneous AF is observed in the AMC produced by the hardness that agitates friction. The result obtained from the composite material showed a significant increase in micro-hardness and wear resistance. H. R. Ezatpour et.al. (2013) in this work, the researchers studied different mechanical properties such as hardness, resistance to performance, maximum tensile strength with a mass fraction of Al2O3 in aluminum. The composite material was produced by shaking. In this process, the author also reported the various parameters such as rpm, injection time, speed, etc., considered for the agitation process. Anilkumar et.al. (2013) this article studies the mechanical and tribological behavior of the AMC compound reinforced by varying the size of fly ash particles. Three sets of composite material were prepared with 75-100 µm, 45-50 µm and 4-25 µm fly ash particles and a comparison study was conducted with aluminum. The result showed a significant reduction in mechanical behavior, such as compressive strength, tensile strength and hardness with increasing particle size of fly ash in AMC compounds with a uniform distribution of fly ash. Grigorios Itskoset et al. (2011) In this report, the Al-Fly A356 ash compounds were synthesized using the pressure infiltration technique, using class C fly metal matrix (MMC) compounds (C) that have an excellent combination of physical, mechanical and tribological properties and its use is still limited due to its high production costs. The fly ash was separated in their fractions of different sizes by manual screening, using their respective sieves. Finally, it has been said that fine particles of fly ash can exploit the properties of the compounds and that the grinding of fly ash facilitates the production of MMC by infiltration under pressure and also benefits from its wear properties.

III. METHODS AND MATERIALS

In this present work, hybrid metal matric composites with aluminium, containing graphite and fly ash particulates, fly ash is procured from thermal power plant. The received fly ash particle sample chemical composition as shown in below Table 1. Graphite crucible is taken and filled with 500 grams of fly ash dust particles, then preheat the granite at 850^0 C for 4 hours to find out the loss on ignition in a muffle furnace. After cooling the preheated granite particles into room temperature was cleaned with distilled water for removing the impurities and remove the moisture content in granite at 120 ^{0}C for 48 hours. Then fly ash particulates will change its colour from grey color to brickish. Dried fly ash powder was filtered for 30 minutes using BSS mesh range in between 100 to 350 Sieve shaker stock. Results show that above 70% of an average particle size of 53µm by weight retained in -200 +350 mesh, so that synthesis of hybrid composites this size was selected as reinforcement. The matrix material of A356 alloy whose chemical composition which is chosen for this work was shown in Table 2.

Muffle furnace was used to melt Al-Si base alloy and its composites which are placed in a graphite melting pot. Stir casting arrangement was shown in Fig. 1 (a). After getting the proper temperature i.e. (700^0C) a vortex was formed. The preheated graphite particles and fly ash dust were rolled into the liquid phase of aluminium in various weight changes of 2 wt.% graphite and 2wt. % fly ash dust in the primary case, again the fly ash weight percentage is enhanced to 4wt. % by maintaining the graphite reinforcement as constant. To provide continuous and the smooth flow of the reinforcement mixture, GI sheet in a conical shape is used, hence the reinforcement of mixture will add the vortex exactly. For comparison purpose, pure graphite particles were reinforced without adding granite powder. Argon gas is passed around the melt to prevent oxidation. The composite finger manufacturing mold is made of grey cast iron was shown in Fig. 1(b).

TABLE I 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 II A356 Alloy Chemical Compositions

Constituent	Si	Mg	Ti	Fe	Cu	Al
wt. %	6.5	0.4	0.06	0.09	0.05	balance

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

A. 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 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.

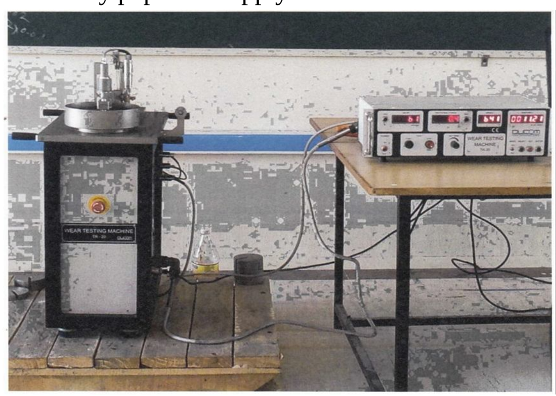

Fig. 2 Ducom TR- 20 LE with Controllers

Fig. 3 Wear Test Specimens

B. 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.

TABLE III
Levels And Their Parameters

Levels	Loads(L) (N)	Time(T) (min)	Reinforcements(R) (Wt.%)
1	5	15	Base alloy A356
2	10	30	2% Graphite
3	15	45	2% Gaphite+4% Fly-ash

C. 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.

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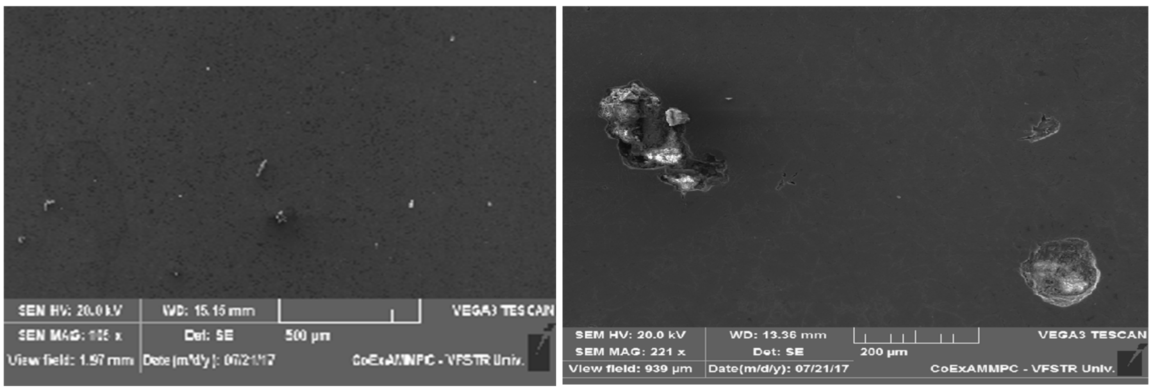
TABLE IV
Comparisons Of Wear (Measured In Micrometer) Results

	A356 Alloy			2 wt.% Graphite			2% wt. Graphite and 4% Fly-ash Dust		
Load(N)	15min	30min	45min	15min	30min	45min	15min	30min	45min
5	95	265	715	65	235	425	35	45	135
10	349	585	898	225	415	660	121	350	397
15	570	1080	1150	450	720	951	381	570	631

D. Composite Microstructures Results and Discussion



(a) (b)

Fig. 4(a) SEM Image of A356 Base Alloy (b) A356 Base Alloy with Fly ash Dust and Graphite Reinforcement

A356 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.

A. 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,

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

Where r = No:of tests condected in a signal trail,
Y = each observed/noticed value.

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B. Result Analysis S/N Ratio

TABLE V
Process Factors OF S/N Ratio

S.No	Applied Loads (N)	Reinforcements (Wt. %)	Sliding Time (min)	Wear (µm)	SNR for Wear
1	5	0	15	95	-39.285
2	5	0	30	265	-48.399
3	5	0	45	715	-57.101
4	5	2	15	65	-35.517
5	5	2	30	235	-47.335
6	5	2	45	425	-52.503
7	5	2+4	15	35	-28.059
8	5	2+4	30	45	-30.981
9	5	2+4	45	135	-42.038
10	10	0	15	349	-50.831
11	10	0	30	585	-55.473
12	10	0	45	898	-59.117
13	10	2	15	225	-46.988
14	10	2	30	415	-52.356
15	10	2	45	660	-56.438
16	10	2+4	15	121	-41.684
17	10	2+4	30	350	-51.105
18	10	2+4	45	397	-51.921
19	15	0	15	570	-55.141
20	15	0	30	1080	-60.833
21	15	0	45	1150	-61.269
22	15	2	15	450	-53.106
23	15	2	30	720	-57.198
24	15	2	45	950	-59.572
25	15	2+4	15	381	-51.764
26	15	2+4	30	570	-55.064
27	15	2+4	45	631	-55.975

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 VI
RESPONSE FOR MEAN WEAR (SMALLER VALUE IS BEST)

Levels	Applied Load(L) Kgf	Reinforcements (R) Wt. %	Sliding Time(T) min
1	226.6	641	260.4
2	451.8	465.2	481.2
3	728.4	300.6	665.1
Delta	501.8	340.4	404.7
Ranking	1	3	2

TABLE VII
SIGNAL-TO-NOISE RATIOS WEAR RESPONCE (SMALLER VALUE IS BEST)

Levels	Applied Loads(L) kgf	Reinforcements (R) Wt. %	Sliding Time (T) min
1	-43.26	-55.01	-45.61
2	-52.70	-52.13	-51.90
3	-57.56	-46.30	-56.05
Delta	14.31	8.76	10.41
Ranking	1	3	2

C. *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.

1) *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

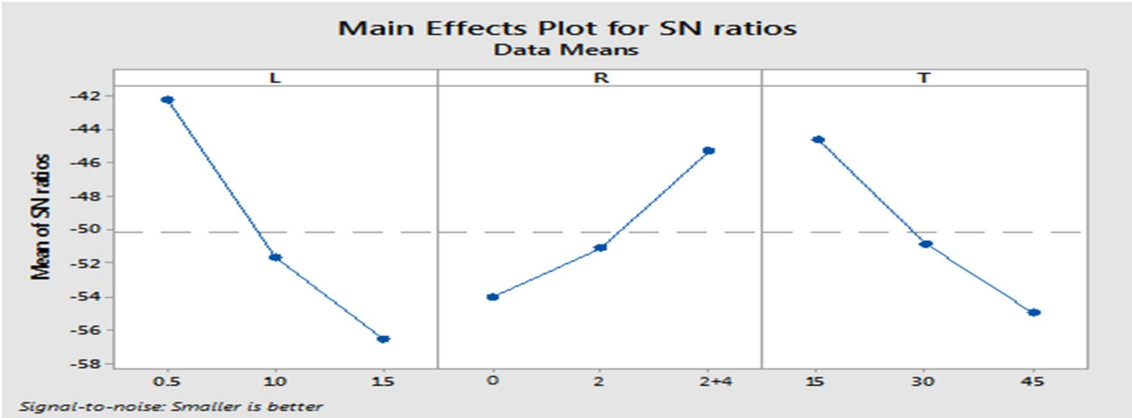

Fig. 6 S/N Ratio of Wear Main Effect's Plot

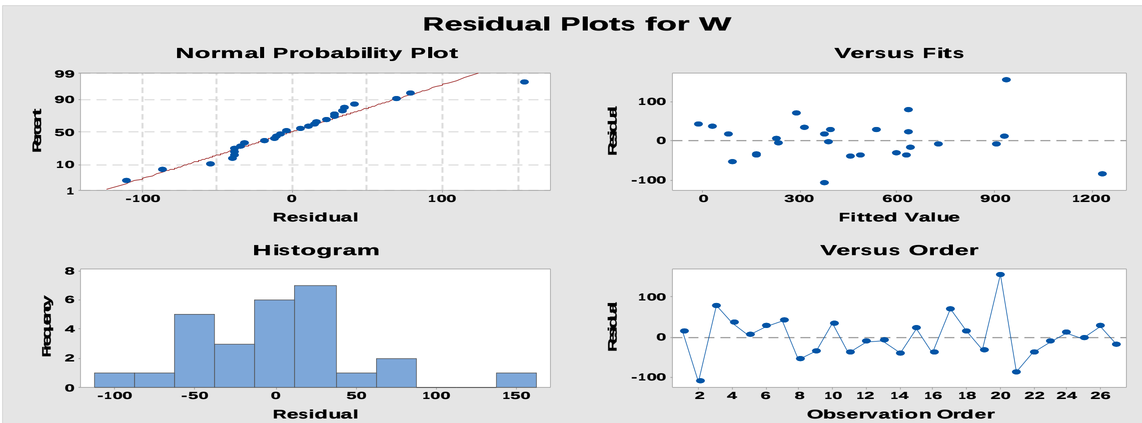

Fig. 7 Error Bars for Wear from Taguchi (W=Wear)

D. 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 leval 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 colume 6 menctions contribution (p) of each element on the total variation on wear and it shows that three elements (L,R,T) having zero weareffects on variation in the outcome. By considering independently all the elements are important. However the imteractional 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 leke L*T and R*T are important to a certain levels

Table VIII. Anova For Wear

Elements	DoF	Sum of Squares	Mean Square	F-value	P-value	% of Contribution
L	2	1137486	568743	120.1	0	42.73
R	2	521746	260873	55.09	0	22.20
T	2	738939	369470	78.02	0	27.47
L*R	4	15165	3791	0.8	0.557	0.58
L*T	4	32897	8224	1.74	0.235	1.27
R*T	4	111019	27755	5.86	0.017	4.28
Error	8	37885	4736	_	_	1.46
Total	26	2595138	_	_	_	100

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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.

Table IX
Model Brief Summaries

S	R-sq	R-sq(adj)
68.82	98.6%	95.3%

E. 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.

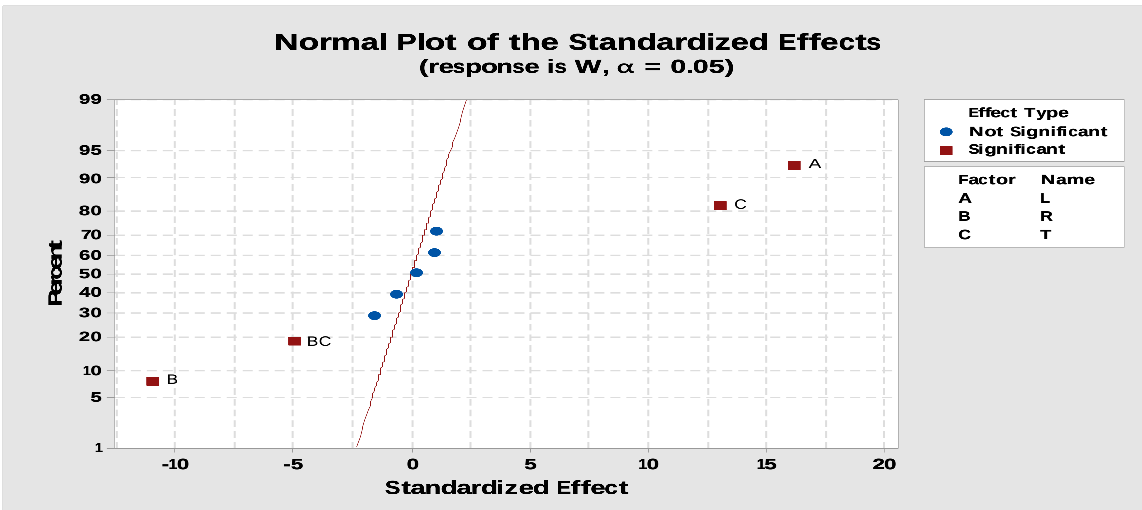

Fig. 7 Standardized Effect of the Normal Plot for Wear in RSM Model (Full Quadratic Form)

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 A356 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 42.73% of applied load on wear is the major contributing element came after 27.47% of sliding time and reinforcement of granite and graphite of 22.20% on wear in the present studying of hybrid composites.

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