International Journal of Research in Engineering, Science and Management
Volume-2, Issue-7, July-2019
www.ijresm.com | ISSN (Online): 2581-5792

Investigation the Tribological Properties of Hybrid Aluminium Metal Matrix Composite

Prakash. S. Sadgir[1], B. V. Varade[2]
[1]*M.E. Student, Department of Mechanical Engineering, R. H. Sapat College of Engineering, Nashik, India*
[2]*Assistant Professor, Department of Mechanical Engineering, R. H. Sapat College of Engineering, Nashik, India*

***Abstract*: Composites based on Aluminium have low specific weight, good casting ability, and inexpensive materials for the aerospace and automotive industries. This paper discusses the tribological properties of hybrid Aluminium metal matrix composite. In this work, tribological properties of Al alloy base LM24 hybrid metal matrix composites reinforced with silicon carbide (pure, 5wt%, 10wt%) and graphite (3wt%) particles was fabricated by stir casting process. The wear and frictional properties of hybrid metal matrix composites were studied by performing dry sliding wear test using pin on disk wear test apparatus. Taguchi's technique was used to conduct experiment. To find major influence factor and regression equation's MINITAB-17 was used. From the experimental data it shows that LM24 + SiC (10%) + Gr (3%) combination has better Wear properties than other combination.**

***Keywords*: Tribology, Hybrid metal matrix composites, Taguchi's technique, MINITAB-17.**

1. Introduction

Metal matrix composite is use tribological application due to excellent wear resistance especially during sliding. However, there is a no study concerning the wear properties of this kind of hybrid metal matrix composite. In the present work studied the tribological behavior of AMC with self-lubricating bearing. Self-lubricating bearings are suited to those situations. In assembly where lubrication is not possible and oil leakage is undesirable. The use of self-lubricating bearings is much favored in machinery dealing with food stuffs or textiles.

2. Research background

A. Vencl et al., (2004) studied the tribological properties of Aluminium based metal matrix composite and its application in automotive industry. Aluminium MMC fabricated by Powder metallurgy method, Squeeze casting method, Compocasting method Vortex method (Stir casting). Low Coefficient of thermal expansion for composite material it is important physical properties. Tensile strength increases in material as reinforcement percentage increases. Wear rate and coefficient of friction decreased as the reinforcement increases. Toyota Motor used diesel engine piston of Aluminium metal matrix composite. Aluminium metal matrix composite used for brake drum and rotor [1].

G. Rajaram et al., (2010) investigate wear behavior Aluminium metal matrix composite at room temperature and elevated temperatures. Materials were selected Al-Si alloy and reinforcement 3wt% graphite. Tensile test taken using instron tensile testing machine also hardness test was conducted using steel ball indenter of 10 mm diameter load of 1000 kgf. Pin diameter ranges from 6 to 13 mm resp. Wear test carried out at various temperature (100, 105, 200, 250, 300, 350ºC) and room temperature. Tensile strength of base alloy and composite was 161MPa and 235 MPa tensile strength of composite higher than the base alloy. This due to uniform distribution of silicon particle with graphite particle. Hardness of composite is greater than base alloy. It shows that temperature effect on wear rate of Al-Si alloy and composite. Composite can perform at temperature 300ºC but alloy withstand with temperature 250ºC. Wear resistance increases by adding particle [2].

V. Muthukumar et al., (2011) studied wear characteristic of Al Alloy (LM4) with SiC as reinforcement. Stir casting technique used to fabricate the material because stir casting technique is simplest, flexible, economical technique. Aluminium were preheated at 1000ºC temp and SiC preheated at temperature 800ºC and mix with molten base alloy. Wear test were carried out with cylindrical sample dimeter 8mm and 40mm length. Disc diameter 55mm and hardness given as HRC65 as provided on pin on disc machine wear test conducted on normal load 0.5, 1, 1.5 kg and fixed sliding speed 500 rpm. It concluded that wear rate decreases as wt% of silicon carbide increases [3].

Venkata siva et al., (2013) studied the Aluminium based composite material which developed from waste colliery shale material. Experiment conducted on pin on disc machine with EN31 steel disc used. The load taken as 20N, 40N, 60N and sliding distance of 1.8kg, 2.16kg, 2.52kg at constant speed 1m/s. Experiment also conducted on Al- Al_2O_3 and Al- Al_2O_3 – SiC composite material and compared to the composite material made from colliery shale material. Result show that the lower wear rate of composite material made from colliery material compared to other composite material [4].

Rachit Marwaha et al., (2013) Metal matrix composite are currently used in aerospace automotive and other industries due to their high strength to weight ratio, hardness and wear resistance and low wear rate the matrix of an alloy based on Aluminium reinforced with particles of silicon carbide and graphite was obtained by the method of stir casting. The wear and friction properties of metal matrix composite were investigated using pin on disc machine the experiment were carried out on the basis of the taguchi experimental plan. An orthogonal array L9 was selected for data analysis. The effect of applied load, sliding speed and track diameter on wear rate and coefficient of friction during wear was investigated by ANOVA [5].

Ravindra kumar et al., (2013) studied the wear behavior of Al-7075 alloy and Al-7075 hybrid composite by response surface methodology analysis. Al-7075 alloy as matrix and silicon carbide and graphite as reinforcement. Wear test carried out at load (30-60N), Speed (2-6 m/s) and Sliding Distance (2000-4000 m). From the experiment it was found that wear resistance of hybrid composite greater than Al-7075 alloy [6].

Gurpreet Singh et al. (2013) studied the optimization of surface roughness processing parameters in hybrid Al / SiC / gr turning. In the experimental work, samples of the composite metal matrix Al / SiC / Gr were prepared by the method of casting with stir. Aluminium alloy reinforced with 10 wt.% SiC and 5 wt.% Graphite. The effect of cutting speed, feed rate and depth of cut on surface roughness was investigated in the process of turning hybrid Al / SiC / Gr MMC. Taguchi L9 Orthogonal array for experimental design. The machining operation is performed using an uncoated tungsten carbide tool. Surface roughness is measured at three different cutting speeds (100, 150 and 200 rpm), three different feed rates (0.2, 0.4, 0.6 mm / rev) and three cutting depths (0.2, 0, 6, 1 mm) (Ra)). Experimental results show that the surface roughness increases with increasing feed speed and cutting depth. The best surface roughness is achieved at a depth of cut = 0.2 mm / rev. Cutting depth and feed rate have a greater effect on surface roughness [7].

T.S.Kiran et al., (2014) investigate the wear behavior of hybrid metal matrix composite. In the experiment matrix was zinc alloy and silicon carbide particle and graphite as reinforcement. Stir casting process were used to fabricated the hybrid metal matrix composite which is simple and economical. Process parameter were taken as load (15, 45, 75), Sliding Distance (1000, 3000, 5000), Sliding Speed (0.63, 1.88, 3.14) then wear behavior were investigated [8].

S.Vinoth Kumar et al., (2014) fabricate and studied the Tribological properties of AA2024 reinforcement with nano SiCp and nano graphite. Material is fabricate by blend-press-methodology with 5 to 10 varying wt % of SiC and 5wt% graphite particle.from the experiment it concluded that density of the AA2024 base alloy. Due to addition of SiC particle the wear resistance and hardness increases [9].

R. H. Naravade et al., (2014) investigated the tribological factor affecting the Al-SiCp-brake pad system. Initially Al6082 was melted at temp 750ºC and SiCp with size 30 to 70 µm preheated then added to the molten material. Cast iron cylindrical disc was made 48mm diameter and 8mm thickness for brake pad application. Pin were first clean with acetone and according to plan of experiment three level and three parameters such as temperature (25 100 175), load (10 15 20), sliding velocity, (0.5 1 1.5) were selected. At the high temperature and load wear rate found to be high [10].

Vijay R Patil et al., (2014) studies on tribological properties of lubricating oil with nanoparticle as an additive. For the experimental work nanoparticle selected as silicon dioxide (SiO_2) and base oil was SN500 to produce highest performance. Silicon act as semiconductor and it has high temperature stability up to 1600ºC. SN500 high quality oil these oil are expensive it having better performance. Nano-oil prepared with eight number of sample with base oil 500ml and varying weight concentration such as 0.1, 0.5 0.75 and 1%. Experiment carried out using pin on disc machine in the experiment track diameter and sliding speed taken as 30mm and 250rpm resp. load applied on pin 10N, 30N, 50N resp. at 10-minute lubricating ability of SiO2 depend on experimental condition [11].

T. Pratheepreddy et al., (2014) Investigate the wear properties of Al/SiC/Gr hybrid metal matrix composite using taguchi and ANOVA. Experiment carried out using pin on disc machine. Material fabricate by stir casting method. Material selected as Al6061 as matrix and the Silicon Carbide and Graphite as reinforcement. According to plan of experiment three parameter Load (10, 20,30N), Speed (200, 600,1000rpm), Track Diameter (50, 80, 110m) Selected. Anova carried out with significance level α=0.05 and confidence level 95% then regression model generated using “minitab 16” wear resistance increases with addition of SiC and Gr particle [12].

Mr. Arunkumar et al., (2014) investigate the tribological properties of Aluminium alloy (LM24) reinforced with graphite, mica Al_2O_3. Percentage of Al_2O_3 of and mica increases then tensile strength and hardness of the material. Stir casting process were used to fabricate the hybrid metal matrix composite which is simple and economical [13].

S. A. Mohan Krishna et al., (2015) studied the thermal expansivity behavior of Al 6061–SiC–Gr hybrid MMC. metal matrix composite is one of the type of composite material. thermal property of hybrid MMC increasingly wide range of application. coefficient of thermal expansion is important factor in the hybrid metal matrix composite. Thermal expensivety find out Aluminium alloy with different weight percentage of silicon carbide and graphite particle. Material with different composition fabricated by using stir casting technique which is commercial available in worldwide. In this experiment Al6061 used as base alloy and reinforcement used as sic and Gr. Microstructure analysis was carried for Al6061with different percentage of reinforcement. By using the microstructural analysis we can find out the distribution of reinforcement material. from the experiment Al6061 gives the high value of thermal expansivity as the varying percentage of reinforcement. Thermal expansivity of aluminium metal matrix composite is decreases due to increase percentage of graphite particle. Changes of thermal expansivity is depend on many factor such as porosity, temperature, internal structure of material [14].

Shubhranshu Bansal et al., (2015) investigate the mechanical and wear Properties of SiC/Graphite Reinforced Al359 Alloy-based Metal Matrix Composite. AL359 alloy used was used as matrix material and silicon carbide and graphite used as reinforcement. Material is fabricated by stir casting method which is economically affordable. Experiment was conducted with different proportions of silicon carbide (0%, 7.5%, 10%) and graphite wear rate of base material and composite are almost similar at low load condition but at higher load the wear rate of Al359-SiC composite is less as compare to Al359-SiC-Gr and matrix alloy [15].

Kehav singh et al., (2017) fabricate and investigate aluminium alloy LM24/B_4C material. In the experimental work LM24 selected as matrix. LM24 has advantage over the LM6 alloy compared to mechanical properties. B_4C used as reinforcement. Tensile test conducted at room temperature with specimen diameter 10mm and 50mm length. It observed that as the wt% B_4C increases tensile strength also increases [16].

Rekha Ganeshkar et al. (2018) studied the wear resistance of metal matrix composites of Aluminium alloy LM6-Al2O3-SiC material is fabricated by using stir casting method LM6 used as matrix material and silicon carbide used as reinforcement. L9 orthogonal array used for the design of experiment microstructure analysis is carried out to find the structure and size from the experiment sliding distance is most effective factor and the temperature is least effective factor due to increase temperature failure of material take place wear rate decreased due to the addition of silicon carbide material. Hardness increases due addition of silicon carbide material [17].

Rahul D. Shelke et al., (2018) studied the properties of Aluminium LM-25-SIC metal matrix composite Fabricated using stir casting method LM 25 was used for base alloy and silicon carbide use as reinforcement. Material is fabricated by stir casting method which is economically affordable. In the stir casting Aluminium alloy heated 800°C then the temperature is gradually Decreases upto the semisolid state and preheated silicon particle mixed into base alloy and mixed Pin on disk apparatus used to dry sliding wear rate. Pin having 12mm diameter and the length 25mm is used to carried out experiment. EN31 steel disk is used by applying load. Low wear rate found Aluminium and silicon carbide composite compared to base alloy. It has found that sliding velocity is most effective factor and the least effective factor is pressure. Uniform Distribution of reinforcement in the matrix alloy is not possible by using stir casting method due to that results are same [18].

3. Material preparation

Among the different manufacturing process for fabrication of Aluminium metal matrix composite. Stir casting is used to fabricate the Aluminium metal matrix composite. In present study LM24 used as matrix its chemical composition given in Table 1 and Silicon Carbide (0, 5, 10 wt%) and Graphite (3 wt%) as Reinforcement. The composite specimen was prepared by stir casting method. The LM24 alloy was heated above its liquidus temperature of 750ºC. A stirrer was introduced in the molten slurry to homogenize the mixture. The mixture of reinforcements were preheated and poured into the rotating molten slurry. To improve the wettability of reinforcements, 1 wt% of magnesium was added along with the reinforcements. The molten slurry was stirred for 10 min, so that the reinforcements distribute uniformly in the alloy. The melt was later poured into permanent castings.

Table 1
Composition of LM24 by Weight Percentage

Material	Wt.%
Mg	0.3
Si	9.5
Fe	1.5
Cu	3
Ti	0.2
Zn	3
Mn	0.5
Ni	0.5
Pb	3
Al	Balance

4. Design of experiment

In this work applied load and percentage of reinforcement were chosen as the independent variables and wear was selected as response variable for the alloy and composites. The statistical software MINITAB-17 was specifically used. By the help Taguchi’s technique L9 orthogonal array was form. In this work objective is to minimize the wear.

Table 2
Design of Experiment

S. No.	Load (N)	Reinforcement (%)
1	10	0
2	10	5
3	10	10
4	20	0
5	20	5
6	20	10
7	30	0
8	30	5
9	30	10

5. Material testing

The dry sliding wear tests were conducted on pin on disc wear testing machine (Model: TR 20LE DUCOM) according to the ASTM: G99-05 standard. The slider disc (EN 31) hardened steel disc having diameter of 165mm and 8mm thickness. The experiment was conducted as per the standard L9 orthogonal array for following parameters and levels shown in TABLE 3. In this process dry sliding wear test was conducted in ambient temperature without any lubrication. Before testing conventional Aluminium alloy polishing techniques are used to make face clean of Aluminium material. The dry sliding wear tests are carried out for two parameters such as applying normal load, percentage of reinforcement. And sliding velocity taken as 1.5m/s constant. In this test applied normal loads taken as

10N, 20N, 30N respectively. and percentage of reinforcement taken as 0wt%, 5wt%, 10wt% respectively. After specimens are tested the measured data are analyzed using the MINITAB-17 statistical software. The result to be studied is the wear with the objective as smaller is the better.

Table 3
Parameter and Level

Level	Load	Reinforcement
1	10	0
2	20	5
3	30	10

Table 4
Orthogonal Array L9 of Taguchi Method

S. No.	Load (N)	Reinforce-Cement (%)	Wear	COF	Temperature
1	10	0	0.06923	0.327	43.71
2	10	5	0.06619	0.228	48.42
3	10	10	0.06223	0.225	49.28
4	20	0	0.08137	0.310	48.57
5	20	5	0.07038	0.300	49.85
6	20	10	0.06612	0.262	51.28
7	30	0	0.09418	0.345	52.28
8	30	5	0.07611	0.335	45.71
9	30	10	0.07013	0.321	50.71

6. Results and discussion

The influence of controlled process parameters such as applied load, percentage of reinforcement and is analyzed. And Means for wear rate and co-efficient of friction is given in tables 5 and 6.

Table 5
Response Table for Means (wear)

Level	Load	Reinforcement
1	0.06588	0.08159
2	0.07262	0.07089
3	0.08014	0.06616
Delta	0.01426	0.01543
Rank	2	1

Table 6
Response Table Means (Friction Co-efficient)

Level	Load	Reinforcement
1	0.2600	0.3273
2	0.2907	0.2877
3	0.3337	0.2693
Delta	0.0737	0.0580
Rank	1	2

Table 7
Response Table Means (Temperature)

Level	Load	Reinforcement
1	47.14	48.19
2	49.90	47.99
3	49.57	50.42
Delta	2.76	2.43
Rank	1	2

7. Analysis of variance (ANOVA) for wear test and friction co-efficient

The analysis of variance (ANOVA) is used to analyze on the wear rate SiC and graphite particulates reinforced LM24 alloy matrix composite as given in table 8. From the table 8, one can easily observe that the Percentage of reinforcement is greater influence on wear rate (48.89%). Hence Percentage of reinforcement is an important control process parameter is further followed by Applied Load (39.78%).

From table 9, one can easily have observed that the Load is greater control on co-efficient of friction (49.71%) than the other factors. Hence, load is a most important parameter to be taken into account while considering co-efficient of friction. Applied load further followed by percentage of reinforcement (31.91%).

From table 10, one can easily observed that the Load is greater control on Temperature (23.20%) than the other factors. Hence, Load is a most important parameter to be taken into account while considering Temperature. Applied load further followed by percentage of reinforcement (18.60%).

8. Multiple regression model

A regression equation is used to develop the relationship between independent predictor variable.

The equation obtained is as follows,

Wear =0.06634 - 0.001543 Reinforcement + 0.000713 Load (1)

COF = 0.2501 + 0.003683 Load - 0.00580 Reinforcement (2)

Temperature = 45.32 + 0.122 Load + 0.224 Reinforcement (3)

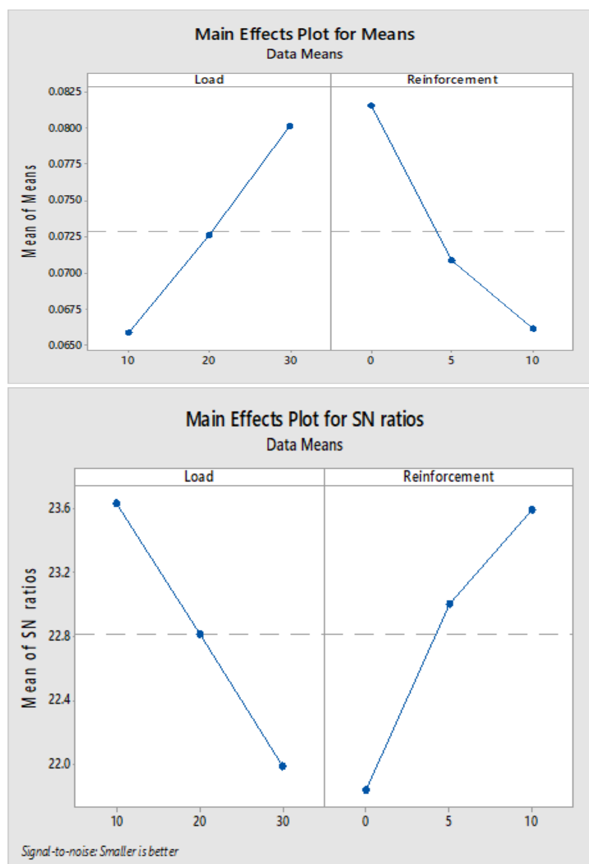

Fig. 1. Interaction plots for wear loss

Table 8
Analysis of variance for wear

Source	DF	Seq SS	Adj MS	Adj MS	F-Value	P-Value	Pr%
Load	2	0.000305	0.000305	0.000153	7.02	0.049	39.78
Reinforcement	2	0.000375	0.000375	0.000188	8.63	0.035	48.89
Error	4	0.000087	0.000087	0.000022			11.33
Total	8	0.000767					100

Table 9
Analysis of variance for friction co-efficient

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value	Pr%
Load	2	0.008216	0.008216	0.004108	5.41	0.073	49.71
Reinforcement	2	0.005274	0.005274	0.002637	3.47	0.134	31.91
Error	4	0.003038	0.003038	0.000759			18.38
Total	8	0.016528					100

Table 10
Analysis of variance for Temperature

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value	Pr %
Load	2	13.65	13.65	6.826	0.80	0.511	23.20
Reinforcement	2	10.94	10.94	5.472	0.64	0.574	18.60
Error	4	34.26	34.26	8.564			58.21
Total	8	58.85					100

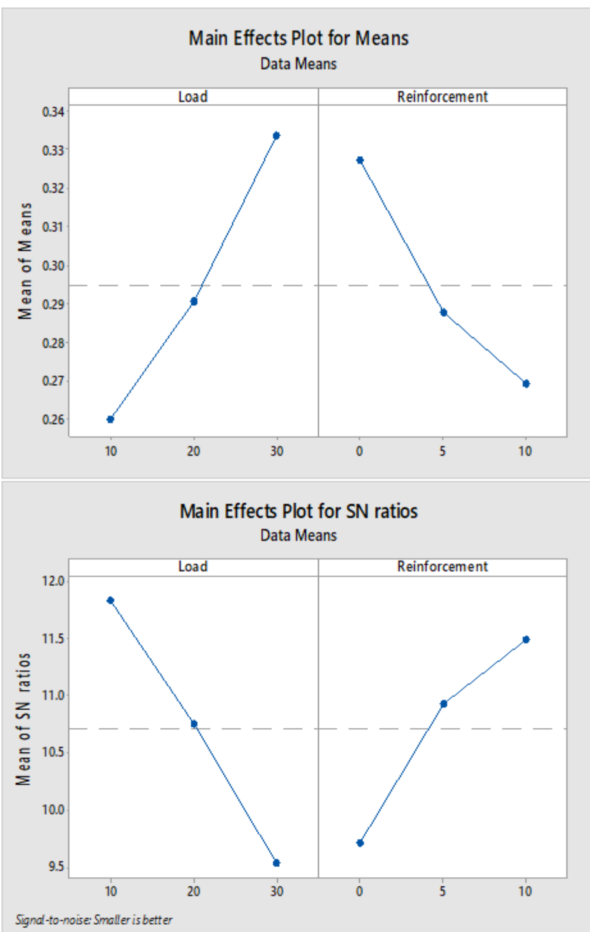

Fig. 2. Interaction plots for coefficient of friction

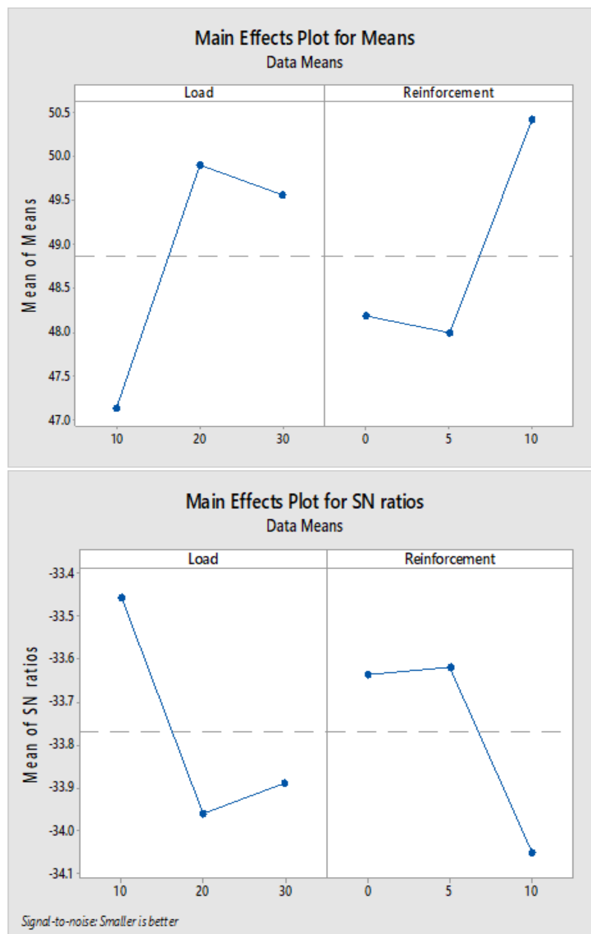

Fig. 3. Interaction plots for temperature

9. Confirmation of experiment

Table 11
Conformation experiment for wear rate and co-efficient of friction

MMCs	Load	Reinforcement	Wear	COF
LM24+ SiC (10%) + Gr (3%)	15	10	0.06472	0.265

Table 12
Result of conformation experiment and their comparison with Regression model

Exp. Wear	Reg. Model Equ. (1), wear	% Error	Exp. Co-Efficient Of friction	Reg. Model Equ. (2), co-efficient of friction	% error
0.06472	0.06160	5.05	0.265	0.247	7.28

10. Conclusion

The following conclusions are drawn from this work:

- The wear resistance of the hybrid metal matrix composites increased with addition of SiC and Gr particle content.
- From the ANOVA it was found that for wear percentage of reinforcement is greater influence factor and for coefficient of friction Load is greater influence factor.
- From the experimental data it shows that LM24 + SiC (10%) + Gr (3%) combination has better Wear properties than other combination.
- Wear of hybrid composites increased with increasing Load and decreases with addition of reinforcement.
- The multiple linear regression models are developed to predict the wear and coefficient of friction.

Acknowledgment

The Authors would like to express sincere thanks to Pravara Rural Engineering College Loni for permitting to carry out the research in the Laboratory and all members who directly or indirectly part of this work.

References

[1] Vencl, A. Rac, I. Bobic, "Tribological Behaviour of Al-Based Mmcs and Their Application in Automotive Industry," vol. 26, No. 3 and 4, 2004.

[2] G. Rajaram, S. Kumaran, T. Srinivasa Rao, M. Kamraj, "Studies on high temperature wear and its mechanism of Al-Si/graphite composite under dry sliding conditions," Tribology international 43, 2152-2158, 2010.

[3] V. Muthukumar, R. Venkatasamy, A. Sureshbabu, K. Jagan, K. Nithin, "Wear characteristics of Al alloy (LM4)- SiC particulate reinforcement MMC," ISSN: 2229-3140, 2011.

[4] Venkata Siva S. B, G. Sreenivasa Rao, K. L. Sahoo, Tribological Studies of Al- based Composite: Developed from a Waste Material, (ICMAME'2013, Singapore) April 29-30, 2013

[5] Rachit Marwaha, Rahul Dev Gupta, Dr. Vivek jain, Krishankant Sharma, "Experimental investigation and analysis of wear parameters on Al/Sic/Gr – Metal matrix hybrid composite by taguchi method," Vol. 13, 2013.

[6] Ravinder Kumar and Suresh Dhiman, "A study of sliding wear behaviors of Al-7075 and Al-7075 hybrid composite by response surface methodology analysis," Material and Design 50, 351-359, 2013.

[7] Gurpreet Singh, Maninder Pal Singh, Gurmeet Singh, "Optimization of the machining parameters for surface roughness during turning of Al/SiC/Gr Hybrid MMC", International Journal of Engineering Research & Technology Vol. 2 Issue 11, November 2013.

[8] T. S. Kiran, M. Prasanna Kumar, S. Basavarajappa, B. M. Viswanatha, "Dry sliding wear behavior of heat treated hybrid metal matrix composite using taguchi techniques," Material and Design 63, 294-304, 2014.

[9] S. Vinoth Kumar, K. Manisekar, P. Ravindran, "Development and tribological performance of nano Sic particles on the AA 2024 hybrid composites with the addition of nano graphite," 2014.

[10] R. H. Naravade, R. K. Belkar, "Statistical analysis of factors affecting the dry sliding wear behavior of Al/SiCp on automobile friction material," ISSN: 2319-1813, 2014.

[11] Vijay R. Patil, Manoj M. Jadhav,Girish B. Pawar Prashant V. Gunjavate "some studies on tribological properties of Lubricating oil with nanoparticles as an Additive" International Journal of Advanced Engineering Technology.

[12] T. Pratheep reddy, N. Amara Nageswara Rao, "Wear optimization of Al/SiC/Gr hybrid MMC using taguchi and ANOVA," ISSN: 2319-8753, Vol. 3, 2014.

[13] Arunkumar, Guruprasad, Satish, Mr.veeranagouda S. Patil "A study on Mechanical and tribological properties of aluminium alloy (LM24), reinforced with mica, Al_2O_3, and graphite" International Journal of Scientific & Engineering Research, Volume 5, Issue 6, June 2014.

[14] S. A. Mohan Krishna, N. Shridhar, L. Krishnamurthy, "computational investigation on thermal conductivity behavior of al 6061–sic–gr hybrid metal matrix composites" International Journal of Computational Materials Science and Engineering Vol. 4, No. 4, 2015.

[15] Shubhranshu Bansal, J. S. Saini, "Mechanical and Wear Properties of SiC/Graphite Reinforced Al359 Alloy-based Metal Matrix Composite", Defence Science Journal, Vol. 65, No. 4, pp. 330-338.

[16] Keshav singh, R.S. Rana, Anjaney Pandey "Fabrication and Mechanical properties characterization of aluminium alloy LM24/B4C composites" Materials Today: Proceedings 4 (2017) 701–708.

[17] Rekha Ganeshkar, Ravindra L. Karwande, Pankaj K. Bhoyar "Experimental Investigation of Wear Properties of Aluminium LM6-Al_2O_3-SiC Metal Matrix Composite" IJSRST, (4) 7.

[18] Rahul D. Shelke, Hitesh Balaram Patil, Navnath S. Kalyankar "Study of Properties of Al LM-25/SIC fabricated by using Stir Casting Method and Wear Analysis by RSM," IJAERS Vol. 5, Issue 2, Feb. 2018.