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Optimization of Dry Sliding Wear Process Parameters for Al-Mg-Si Hybrid Composites Using Taguchi Method

Abstract: *The aim of the presents study was to investigates the influence of different sliding velocity 1.4, 2.8, 4.2 m/sec, applied load 5, 10, N and time 10, 20, 30 min on wear rate of Al-Mg-Si alloy reinforced with varying weight fraction of TiO_2/SiC 1.5:0 ,3:0 , 4.5:0 , 0:1.5 , 0:3 , 0:4.5 , 1.5:1.5 , 3:3 , 4.5:4.5 wt.% with the same particle size (>75µm) by using pin-on-disk techniques. In this research Al-Mg-Si alloy TiO_2/SiC hybrid composites was prepared by vortex technique. The primary objective is to use taguchi method for predicting the better parameter that give the highest wear resistance. A L9 orthogonal array was selected for each present to analysis of data and use ANOVA to determine parameters significantly influencing the wear rate of hybrid composite. Optical microscope and SEM with EDS examination were utilized to study the worn surface. The experimental and analytical results showed that the taguchi method was successful in predicting the parameters that give the highest properties and the volume fraction was the most influential parameter on the wear rate. The results demonstrated that when the applied load and time increased the wear rate increasing, but when the sliding velocity increased the wear rate decreasing and showed the minimum wear in hybrid composite with 4.5% reinforcement this observed with highest ratio of S/N 156.787.*

Keywords- vortex method, pin-on-disk, Al-Mg-Si/TiO_2/SiC composite, taguchi method, ANOVA

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1 Introduction

The metal matrix hybrid composite materials are advanced materials which combine a hard ceramic particulates in tough metallic matrix. These materials have superior properties when compared to the monolithic materials. Metal matrix composites show advantages in a great number of specific applications (air craft, automobile, machines) due to their high stiffness, strength, wear resistance and dimensional stability [1] Aluminum alloys have attracted concern of many researchers, designers and engineers as promising structural materials for aerospace applications or automotive industry [2]. It is so attractive because of their good corrosion resistance, wear resistance, low density, high thermal and electrical conductivity, capability to be strengthened by precipitation and their high damping capacity[3][4]. Suresh and Prasanna Kumar [5] 2013, studied the Al6061MMCs wear resistance. Al6061 MMC composite included 2,4,6 and 8% of alumina with fixed percent of graphite 2% fabricated by stir casting, the wear test by used pin on disk method was carry out with range of load10-50N and sliding distances of 1-3km and for various sliding speed 1.88-5.65 m/s, the coefficient of friction and wear rate showed decreased with increasing weight percentage of Al_2O_3. Vinod Kumar et al. [6] 2014, An attempt has been made to increase the an Al6061 alloy tribological property by reinforcing with addition 15% of Al_2O_3 and SiC particulates respectively, The method of pin-on-disc was utilized to study the test of wear, the applied loads (25N, 30N and 35N) for sliding distance (100m, 1500m and 2000m) at different sliding speed (2.0m/s, 2.25m/s and 2.5m/s), the results presented that the applied load has highest effect on the rate of wear then sliding distance and sliding speed. One of the most important optimization processes is taguchi method it's a powerful tool for the design of high quality system [7].It was a simple

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efficient and systematic approach to optimize design for performance cost and quality. The taguchi approach enables a comprehensive understanding of the individual and combined from a minimum number of simulation trials. This method is multi step process which follow a certain sequence for the experiments to yield an improved understanding of product or process performance [8,9] The aim of this research is study the wear behavior with three different applied load, time and sliding speed for Al-Mg-Si reinforced by SiC and TiO_2 particles that produced by stir casting way.

2. Experimental Work

In this research we used two type of particles (SiC and TiO_2) with particle size (<75µm) as reinforcement phase embedded in Al-Mg-Si as matrix phase. The table (1) shows the chemical composition of the alloy that has been done in the laboratories of State Company for Inspection and Engineering Rehabilitation- Ministry of Industry and Minerals by using SPECTRO MAX machine. The alloy was melted in alumina crucible at temperature 700 ^{o}C in the electric furnace (local industry) and then pouring in the preheated steel mold at 250 ^{o}C to prepared base alloy. The composites have been prepared by stir casting method, where it was melting the base alloy in electric furnace at 750^{o}C which is above the liquidus temperature. The melt was held at this temperature for approximately 15 min for homogenization chemical composition, then added flux(1%wt.). The reinforcing materials (silicon carbide and/or titanium oxide) gradually added to melting alloy along with mechanical stirrer, particulates added with 1.5:0 ,3:0 , 4.5:0 , 0:1.5 , 0:3 , 0:4.5 , 1.5:1.5 , 3:3 , 4.5:4.5 wt % were utilized, where they were wrapped by aluminum foil and preheated to 550^{o} C for 1 hour (to remove moisture and to help improve wettability with the Al-Mg-Si alloy melt) after making vortex within melting by electric stirrer rotational speed (800 r.p.m) so as to obtain good dispersion of the reinforcing within the melt. Magnesium has been added (1wt%) to improve the wettability between the base metal and reinforcement. Then, pouring the melt in the preheated mold to get a composite material reinforcing by SiC and/or TiO_2 particles, and the process is repeated for all additions.After the preparation of all samples of the base alloy and composites it has been done a machining process(turning) for castings according to the standard dimensions required for each test.

Table1: chemical composition of Al-Mg-Si alloy (wt %)

Elements wt%	Si	Fe	Cu	Mn	Mg	Cr	Ti	Zn	Al
Casting alloy	0.530	0.270	0.181	0.041	0.954	0.067	0.014	0.004	Bal.
Standard alloy	٠.٤-٠.٨	Max 0.7	-٠.٤ ٠.١٥	Max 0.15	0.8-1.2	- ٠.٠٤ ٠.٣٥	Max 0.15	Max 0.25	٩٥.٨ ٩٨.٦-

3. Taguchi Technique

Taguchi design of experiment is a powerful analysis tool for modeling and analyzing the influence of control factors on performance output. The most important stage in the design of experiment lies in the selection of the control factors. Therefore, a number of factors are included so that non-significant variables can be identified at earliest opportunity. Taguchi method provides a simple, systematic and efficient methodology for the optimization of the control factors [10].

4. Examinations and Tests

The specimens of wear test have been examined utilizing Scanning electron microscopy and Energy dispersive spectrometer (EDS) detector have been used type of (VEGA 3 LM) produced by TESCAN a Czech to study the topographic of reinforcements and specimens and to obtain the micro-chemical composition. Wear test was carried out by wear device of (pin on disk) local industry. This consists of a disk of rotating speed (490 r.p.m) and specimen holder .The device contains a motor of rotational speed fixed amount (940r.p.m) where the disk hardness (HV =217). Specimens were prepared for test with (10 mm in diameter and 20 mm high) were cut from cast samples, machined, and then grinding. The surface roughness was 1.4 µm. The wear rate is calculated by weighting method, the changes of relative mass are measured by weighing the samples before and after tests utilizing a digital balance with an accuracy of ±0.0001 g. The loads utilized were (5, 10and 15 N) and with different sliding speed (1.4, 2.8, 4.2m/sec) and time (10, 20 and 30 min.) . The disc was cleaned and polished after each test and the surface roughness was 1.7 µm. Wear rate has been calculated utilizing the following equation [11]:-

$$Wear\ rate = {}^{\Delta W}/_{SD}\ \ ({}^{g}/_{cm}) \quad ....(1)$$

Where:

ΔW: The different in weight of sample before and after the test (g)

SD: Sliding distance (cm)

$$SD = Vt \quad ....(2)$$

Where :

V: Linear sliding speed (m/sec).

t: Testing time (min).

The wear parameters chosen (for base alloy and composites) for the experiment in research were: load (N), sliding speed (m/s) and time (min) and for each parameter has three levels that is given in table (2). In the present investigation, a L9 orthogonal array was selected consists of nine tests for each percentage of composite. Formula (3) utilized to calculate the ratio of S/N.

$$S/_{N} = -10\log\left(\frac{1}{n}\sum y^{2}\right) \quad ....(3)$$

where

S/N: The ratio of the mean signal (S) to the noise (N) standard deviation.

n: Number of tests.

Y: Response factor.

Table 2: The parameters and their levels of wear rate

Level	Load (N)	Speed(m/s)	Time (min)
1	5	1.413	10
2	10	2.827	20
3	15	4.241	30

5. Result and discussion

The most important factor to obtain a homogeneous property of discontinuously reinforced composites material is the uniform dispersion of the reinforcement particles. Figure (1,2,3,4) show the microstructure almost spherical in shape and their distribution is uniform reasonably throughout the matrix in a company with coalecenance of particles at some locations. It is expected that the bonding between the reinforcing particles and Al-melt would result in an interaction layer which enhances wetting between the particles and the matrix. The interfacial reaction between the metal matrix and reinforcement in metal matrix composites (MMCs) is very important because strong interfacial bonding permits the transfer and distribution of the load from the matrix to the reinforcement [12].Wear test of dry-sliding has conducted on the single, hybrid composites and unreinforced alloy of aluminum. The loss of weight of the specimens were calculated by finding the various between initial and final weight. Experiments were conducted accordance to the orthogonal array and the corresponding values of wear rate. The influence of input process parameters on wear rate were determined using S/N ratio. The parameter with the highest S/N ratio gives minimum wear rate. The measured values of weight loss for all samples tested were converted into rate of wear as shown in tables (3-12) and the present the ratio of S/N. The data of weight loss of alloy sample were utilized to studding effect of silicon carbide SiC and titanium oxide TiO_2 addition and the parameter of sliding velocity, load and time at the wear resistance of single and hybrid composite materials. The influence of input process parameters on wear rate were determined using S/N ratio gives minimum wear rate. The optimum experimental that can be show in table (13). The hybrid composite of 4.5%TiO_2 and 4.5%SiC shows highest ratio of S/N.Study the effect of weight percentage of addition on rate of wear has been done for the base alloy and composites at different load (5, 10 and 15 N) and sliding speed (1.4, 2.8 and 4.2m/sec) with testing time (10, 20 and 30 min). Figure (5) shows the relationship between the percentage of particles and rate of wear where the rate of wear inversely proportional with percentage of particles for both base alloy and composites and showed that the base alloy has rate of wear more than composites. It was seen that the lower rate of wear for hybrid composites was at (4.5%). The results showed that the increase of proportion of TiO_2 and SiC increased the hardness, where the hardness is inversely proportional to the wear rate is being reduced from plastic deformation. In addition to the role of these particles to bearing the load Figure (6) shows the optimum specimen after wear by utilize SEM and EDS. From the EDS examination, it was observed that the presence of iron particles that transfer from the disc to the specimen due to hard particles reinforcement, whereas figures (7 and 8) show the effect of applied load on the samples of base alloy and composites after wear test by utilizing optical microscopy. It was observed that the worn out surfaces mainly consist of partially irregular pits and longitudinal grooves, it can be concluded from microstructure study that mostly abrasive wear occurs with some traces of adhesive wear. The figures (7) and (8) showed that the wear debris on surface of the base alloy and composites samples increases with increasing load. It was observed that when the loads are low it was found that shallow grooves in the direction of sliding and slid paths are close and not deep and some areas covered with a layer of oxide as a result of the heat generated, and it indicates that the oxidation wear occurred[13]. With increase loads the width of wear lines are increased and became grooves with observation of small and large cracks spread on surface of samples, where the convergence of these cracks the debris are form. In addition, some particles of silicon carbide or titanium oxide leave the matrix and transition as third body between sample and the hard disk while with a high load gets abrasive wear with increasing distortion of sample surface. Some particles may crush because its hardness inside soft matrix causing a larger distortion for sample surface [14].

Figure1:The microstructure of base alloy(Al-Mg-Si)

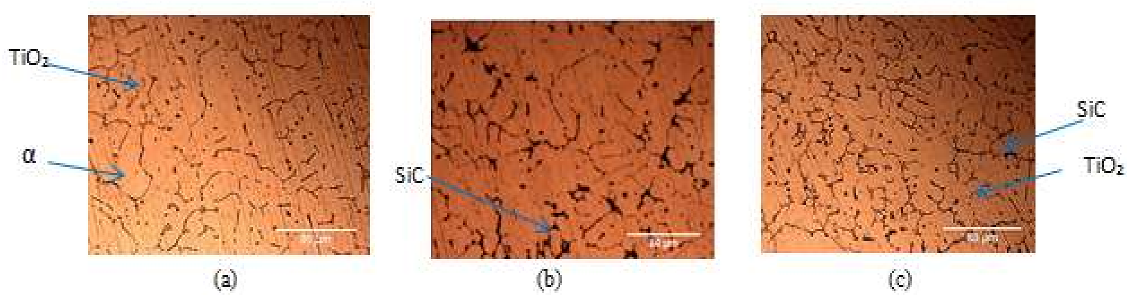


Figure 2: Microstructure of (a) composite 1.5%TiO_2, (b) composite 1.5%SiC, (c)1.5% hybrid

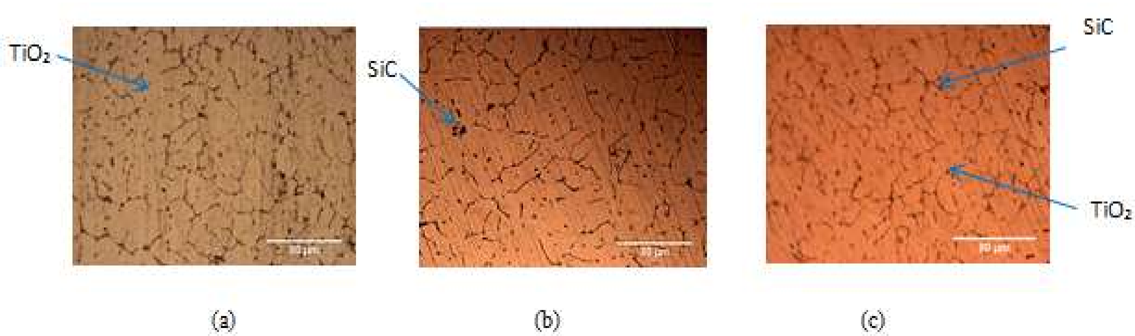


Figure 3: Microstructure of (a) composite 3%TiO_2, (b) composite 3%SiC, (c)3%hybrid composite

(a) (b) (c)

Figure 4: Microstructure of (a) composite 4.5%TiO_2,(b) composite 4.5%SiC, (c) 4.5%hybrid composite

Table 3: Results of Taguchi experiments for wear rate of as cast Al-Mg-Si alloy

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Wear Rate (gm/cm)	S/N Ratio
1	5	1.4	10	7.571*10^-7	122.413
2	5	2.8	20	1.899*10^-7	135.057
3	5	4.2	30	2.385*10^-7	132.444
4	10	1.4	20	11.27*10^-7	118.950
5	10	2.8	30	7.252*10^-7	122.786
6	10	4.2	10	7.817*10^-7	122.134
7	15	1.4	30	6.180*10^-7	124.152
8	15	2.8	10	14.078*10^-7	117.881
9	15	4.2	20	2.182*10^-7	133.217

Table 4: Results of Taguchi experiments for rate of wear of composite 1.5%TiO_2

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Rate of wear (gm/cm)	S/N Ratio
1	5	1.4	10	3.424*10^-7	129.305
2	5	2.8	20	0.611*10^-7	144.272
3	5	4.2	30	0.754*10^-7	142.452
4	10	1.4	20	5.539*10^-7	125.126
5	10	2.8	30	2.770*10^-7	131.190
6	10	4.2	10	5.391*10^-7	125.362
7	15	1.4	30	2.217*10^-7	133.082
8	15	2.8	10	3.390*10^-7	129.392
9	15	4.2	20	1.423*10^-7	136.929

Table 5: Results of Taguchi experiments for rate of wear of composite 1.5%SiC

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Rate of wear (gm/cm)	S/N Ratio
1	5	1.4	10	3.047*10^-7	130.317
2	5	2.8	20	0.623*10^-7	144.105
3	5	4.2	30	0.676*10^-7	143.392
4	10	1.4	20	3.407*10^-7	129.347
5	10	2.8	30	2.655*10^-7	131.513
6	10	4.2	10	3.728*10^-7	128.567
7	15	1.4	30	1.507*10^-7	136.428
8	15	2.8	10	3.206*10^-7	129.874
9	15	4.2	20	1.379*10^-7	134.754

Table6: Results of Taguchi experiments for rate of wear of 1.5%hybrid composite

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Rate of wear (gm/cm)	S/N Ratio
1	5	1.4	10	1.760*10^-7	135.045
2	5	2.8	20	0.369*10^-7	148.653
3	5	4.2	30	0.594*10^-7	144.523
4	10	1.4	20	2.132*10^-7	133.420
5	10	2.8	30	1.279*10^-7	137.855
6	10	4.2	10	1.879*10^-7	134.514
7	15	1.4	30	1.275*10^-7	137.881
8	15	2.8	10	1.931*10^-7	134.279
9	15	4.2	20	1.274*10^-7	137.892

Table7: Results of Taguchi experiments for rate of wear of composite 3% TiO_2

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Rate of wear (gm/cm)	S/N Ratio
1	5	1.4	10	1.666*10^-7	135.565
2	5	2.8	20	0.393*10^-7	148.114
3	5	4.2	30	0.688*10^-7	143.242
4	10	1.4	20	2.593*10^-7	131.662
5	10	2.8	30	2.010*10^-7	133.831
6	10	4.2	10	3.068*10^-7	130.261
7	15	1.4	30	2.174*10^-7	133.739
8	15	2.8	10	3.102*10^-7	130.167
9	15	4.2	20	1.181*10^-7	138.546

Table 8: Results of Taguchi experiments for rate of wear of composite 3% SiC

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Rate of wear (gm/cm)	S/N Ratio
1	5	1.4	10	1.571*10^-7	136.073
2	5	2.8	20	0.307*10^-7	150.250
3	5	4.2	30	0.599*10^-7	144.447
4	10	1.4	20	1.908*10^-7	134.386
5	10	2.8	30	1.914*10^-7	134.359
6	10	4.2	10	1.251*10^-7	138.054
7	15	1.4	30	1.343*10^-7	137.437
8	15	2.8	10	3.090*10^-7	130.200
9	15	4.2	20	1.077*10^-7	139.348

Table 9: Results of Taguchi experiments for rate of wear of 3% hybrid composite

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Rate of wear (gm/cm)	S/N Ratio
1	5	1.4	10	1.208*10^-7	138.352
2	5	2.8	20	0.265*10^-7	151.506
3	5	4.2	30	0.541*10^-7	145.326
4	10	1.4	20	1.618*10^-7	135.943
5	10	2.8	30	1.008*10^-7	139.927
6	10	4.2	10	1.133*10^-7	138.915
7	15	1.4	30	0.957*10^-7	140.380
8	15	2.8	10	1.813*10^-7	134.440
9	15	4.2	20	1.064*10^-7	139.459

Table 10: Results of Taguchi experiments for wear rate of composite 4.5% TiO_2

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Wear Rate (gm/cm)	S/N Ratio
1	5	1.4	10	1.074*10^-7	139.369
2	5	2.8	20	0.259*10^-7	151.701
3	5	4.2	30	0.543*10^-7	145.305
4	10	1.4	20	2.410*10^-7	132.357
5	10	2.8	30	0.912*10^-7	146.259
6	10	4.2	10	3.629*10^-7	131.065
7	15	1.4	30	0.847*10^-7	138.349
8	15	2.8	10	1.417*10^-7	135.145
9	15	4.2	20	1.156*10^-7	138.736

Table 11: Results of Taguchi experiments for wear rate of composite 4.5% SiC

Exp. No.	**Load (N)**	**Sliding Speed (mm/sec)**	**Time (min)**	**Wear Rate (gm/cm)**	**S/N Ratio**
1	5	1.4	10	1.078*10^-7	139.340
2	5	2.8	20	0.245*10^-7	152.189
3	5	4.2	30	0.459*10^-7	146.764
4	10	1.4	20	2.132*10^-7	134.884
5	10	2.8	30	0.882*10^-7	141.087
6	10	4.2	10	1.006*10^-7	139.938
7	15	1.4	30	0.346*10^-7	146.085
8	15	2.8	10	0.986*10^-7	139.562
9	15	4.2	20	0.885*10^-7	141.059

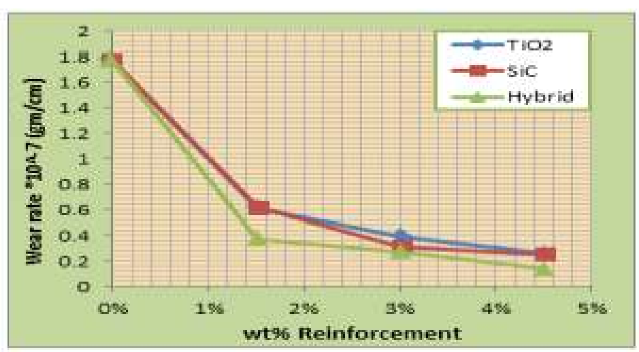
Table 12: Results of Taguchi experiments for wear rate of 4.5% hybrid composite

Exp. No.	Load (N)	Sliding Speed (mm/sec)	Time (min)	Wear Rate (gm/cm)	S/N Ratio
1	5	1.4	10	0.565*10^-7	144.064
2	5	2.8	20	0.136*10^-7	156.787
3	5	4.2	30	0.401*10^-7	147.931
4	10	1.4	20	1.205*10^-7	138.378
5	10	2.8	30	0.402*10^-7	147.920
6	10	4.2	10	0.857*10^-7	141.334
7	15	1.4	30	0.228*10^-7	152.824
8	15	2.8	10	0.614*10^-7	144.230
9	15	4.2	20	0.800*10^-7	141.931

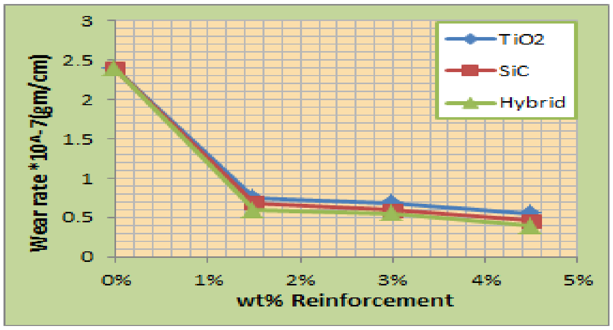
Table 13: Optimum design of parameters as a function of different conditions

Sample	Highest Ratio of S/N	Exp.No.
Alloy	١٣٤.٥٤٩	2
1.5%TiO2	١٤٤.٢٧٢	2
1.5%SiC	١٤٤.١٠٥	2
Hybrid1.5%	١٤٨.٦٥٣	2
3%TiO2	١٤٨.١١٤	2
3%SiC	١٤٩.٣٠٢	2
Hybrid3%	١٥١.٥٠٦	2
4.5%TiO2	١٥١.٥٠٦	2
4.5%SiC	١٥٢.١٨٩	2
Hybrid 4.5%	١٥٦.٧٨٧	2

(Ex.1)



(Ex.2)



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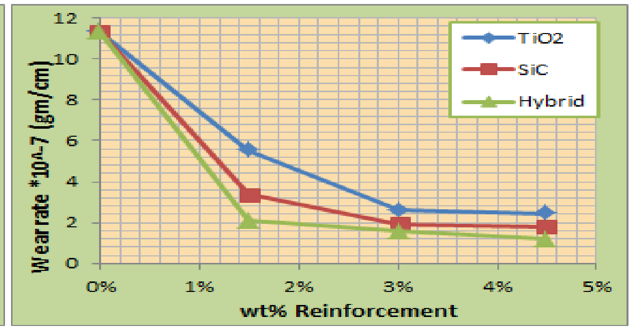

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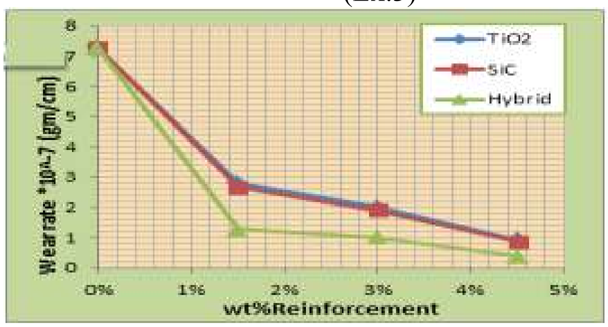
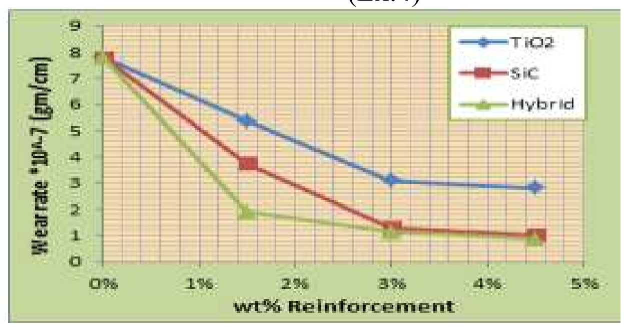
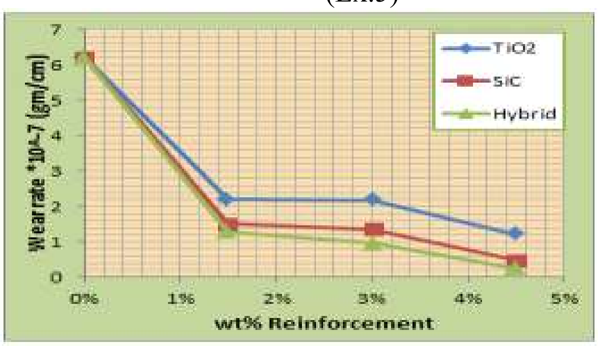


(Ex.5)

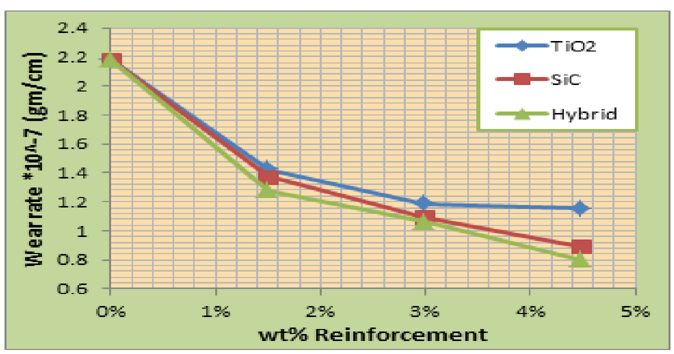


(Ex.6)



(Ex.7)

(Ex.8)



(Ex.9)

Figure 5: the relationship between rate of wear with weight percent of reinforcement during the wear test

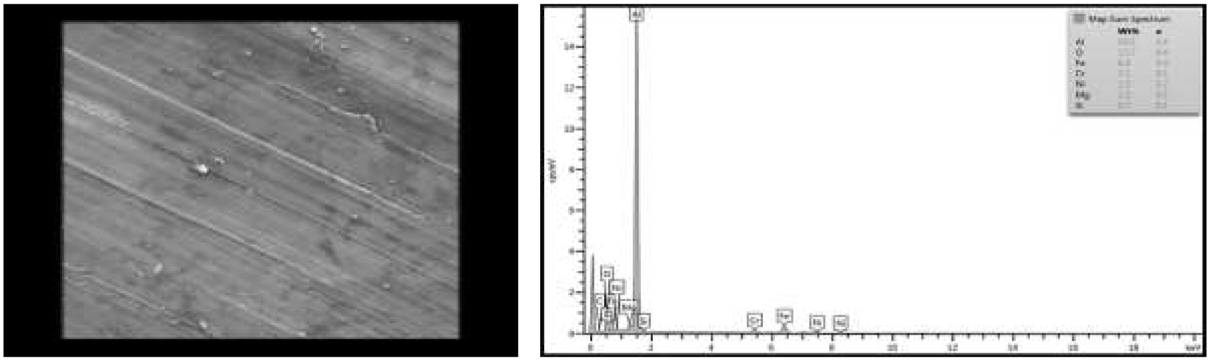
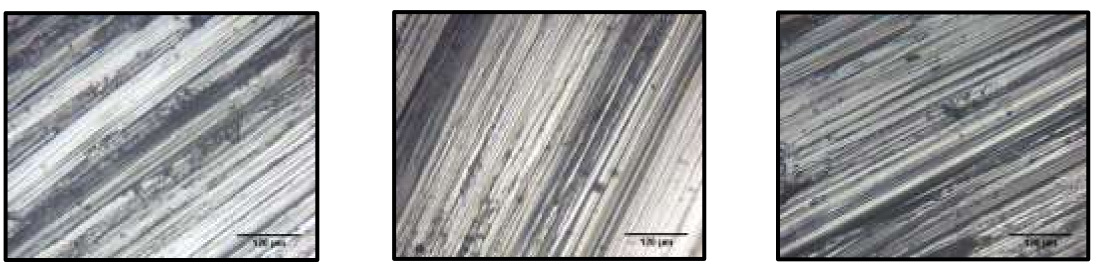


Figure 6: a-SEM image for the optimum specimen of 4.5% hybrid composite after wear test
b- EDS result of same specimen

(a) **(b)** **(c)**

Figure7: The microstructure of Al-Mg-Si alloy after wear test (a) 5N applied load of (Ex.No.2), (b) 10N applied load (Ex.No.5), (c) 15N applied load (Ex.No.8)



(a) **(b)** **(c)**

Figure8: The microstructure of 4.5%hybrid composite after wear test (a) 5N applied load of (Ex.No.2), (b) 10N applied load (Ex.No.5), (c) 15N applied load (Ex.No.8)

6. Conclusion

It may be mentioned the most important conclusions reached in this research, as follows:

1-Wear rates are reduced with addition of TiO_2 and SiC particle in a composite material that the reduction in the wear rate increases with increasing percentages of particles and minimum wear rate was found at about adding 4.5% hybrid composite.

2- Wear rate is directly proportional with the load meaning it increases with load on base alloy and composite.

3- Wear rate is reduced of the base alloy and a composite with the increased sliding speed.

4- the microstructure of the base alloy improved after the addition of titanium oxide and silicon carbide particles by refining the grains.

Reference

[1] Kumarb, S.D.Saravanana and M.Senthil, "Effect of Mechanical Properties on Rice Husk Ash Reinforced Aluminum alloy (AlSi10Mg) Matrix Composites", International Conference On DESIGN AND MANUFACTURING, IConDM 2013, pp. 1505-1513, 2013.

[2] I. A. Alkadir, "Studying The Effect Of Reinforcing By Sicp On The Dry Sliding Wear Behavior And Mechanical Properties Of Al- 4% Cu Matrix Alloy", Diyala Journal of engineering sciences, Vol. 06, No. 02, pp. 139-153, June 2013.

[3] J. J. Rino, D. Chandramohan and V. Daniel Jebin, "Research Review On Corrosion Behaviour Of Metal Matrix Composites", International Journal of Current Research, Vol. 4, Issue, 09, pp.179-186, September, 2012.

[4] S.M. Ausama, "Microstructure and Wear Rate of Yttria Reinforced Aluminum – Silicon Matrix Composites", Engineering and Technology Journal, vol.28, no. 23, pp.1184-1196, 2010

[5] Kumar, Suresh R and M. Prasanna, "Investigation of Tribological Behavior and Its Relation with Processing and Microstructures of Al6061 Metal Matrix Composites", International journal of research in engineering and technology (IJRET) , vol. 1, no. 2, pp. 91-104, 2013.

[6] V.Kumar, P. kumar and S. sharma, "Wear Characterization of Aluminum/SiC/Al_2O_3 Hybrid Metal Matrix Composite Using Taguchi Technique", International Journal of Innovative research and development, vol. 3, no. 1, pp. 34-40, 2014.

[7] G. Taguchi , S. Konishi , "Taguchi methods orthogonal arrays and linear graphs tools for quality engineering", American Supplier Institute, pp. 35-36, 1987.

[8] G. Taguchi , " Taguchi an robust technology development methods", New Yourk, NY:ASME press, pp.1-10, 1993.

[9] S.Basavarajappa, G. Chandramohan, J.Paulo Davim, "Application of taguchi techniques to study dry sliding wear behavioure of metal matrix composites, materials and design", vol. 28, no.21, pp.1393-1398, 2007.

[10] H. Kumar.T.R., Swamy.R.P. and Chandrashekar T.K., "Taguchi Technique for the Simultaneous Optimization of Tribological Parameters in Metal Matrix Composite", Journal of Minerals & Materials Characterization and Engineering, vol. Vol. 10, no. No.12, pp.1179-1188, 2011.

[11] Mediratta, D. Singla and S.R., "effect of load and speed on wear properties of Al 7075-fly ash composite material," International Journal of Innovative Research in Science, Engineering and Technology , vol. 2, no. 5, pp. 1-9, 2013.

[12] B.K.Raghunath, G. Elango, "Tribological Behavior of Hybrid (LM25Al + SiC+ TiO2) Metal Matrix Composites", International Conference On DESIGN AND MANUFACTURING, no. 64, p. 671 – 680, 2013 .

[13] A. A.Bandar , M. K. Abbas and sherean K.T., "Studying Some Mechanical Properties and WearResistance of Aluminum - Glass Composites", Engineering and Technology Journal, vol.28, no. 21, pp.1030-1039, 2010.

[14] W. T. Rashid, "studing dry mechanical corosion for composite material of base (Al-4%Cu/SiC)", University of technology, Baghdad, 2012.

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