MAT JOURNALS
Journal of Advancements in Material Engineering
Volume 4 Issue 2

Mechanical Properties and Triobological Behavior of Stir Cast Al-6063 Alloy Based Hybrid Composite

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***DOI:** http://doi.org/10.5281/zenodo.3245759*

Abstract

India is one of the developing countries that need to face the many challenges in automotive industry. In industries usage of heavier materials are replaced by aluminium alloys because of its good properties. The objective of this work is investigating the influence of quarry gravel powder (QGP), silicon carbide (Sic) and fly ash (FA) particles of fraction percentage on the mechanical properties and wear behavior of Al6063 based alloy metal matrix composites. The abrasive ceramic particles, fly ash and gravel powder reinforced in the metal matrix are the cause of improvement in mechanical and tribological properties of the materials. The al 6063 metal matrix hybrid composite consist of 4 wt%, 6 wt%, and 8 wt% QGP-SiC–FA respectively was processed by using stir casting technique procedure. Tribological Wear behavior of the developed hybrid composites was characterized at different loads, sliding velocities and distances using pin-on-disc method. The experimental results are discuss that the applied load and reinforcement of wt% are the major parameters influencing the specific wear rate for all samples, followed by weight fraction of reinforcement, sliding velocity and sliding distance.

***Keywords:** AL 6063, density, fly ash, hybrid metal matrix composite, micro hardness, SIC, stir casting, quarry gravel powder, wear*

INTRODUCTION

The metal matrix hybrid composites have higher level mechanical properties when compared to the rigid materials. The dimensional fastness, high strength, high severity, wear behaviour etc make them available for extensive range of engineering application. Quarry gravel powder, fly ash, ceramics, E-wastes, marine wastes and agro waste ashes are waste materials which are available abundantly in the entire world. Simultaneously, aluminum metal matrix hybrid composites (Al MMHCs) are using overall in various structured and tribological applications. These aluminum hybrid composites possess higher level properties such as higher specific modulus, stiffness, hardness, lower density, better wear resistance, lower heat expansion of coefficient and well balanced properties at upraised temperatures. Main of the aerospacis implementations, titanium alloys have been adapted by aluminum alloys [1-2].

Aluminium metal matrix hybrid composites reinforced with fly ash and abrasive silicon carbide by utilize current methods shows increasing trend for many properties of them increase in reinforcement proportion, other than the density will decreases with the increase in the reinforcement proportions. Present studies concentrate both of them experimental and analytical approaches of Al MMHCs for better mechanical properties and good wear behavior [3].

Improvement of mechanical and tribological properties depends majorly on fabrication techniques like powder metallurgical methods, friction stir techniques, bottom pouring stir casting and squeeze casting to produce particulate reinforced Al MMCs. Based on literature review of the above techniques, bottom pouring stir casting techniques was supposed to be the easiest and the most economy procedure for fabricating particulate reinforced MMHCs [4].

The performance of MMCs described by tribological behaviour such as wear behaviour and coefficient of friction are the crucial factors. The wear and friction behaviors of Al MMCs use to obtain by pin-on-disc test. In this test, bars of Al MMHCs slide to against EN32 hardened steel disc or cast iron disc under several loads. The results bear that the increasing abrasive SiC, decreases the wear behaviour. Whereas coefficient of friction increases with the increasing of SiC. Wear behaviour of composite materials differs by means of the applied load and sliding velocity. Increase in sliding speed and load leads the wear rate increases. Addition of reinforcement to aluminum matrix alloys increases the wear resistance of composite materials [5-6].

EXPERMENTAL PROCEDURE

Materials and Methods

The al-6063 is an aluminum; in this main magnesium and silicon are the alloying elements. The standard management of its composition is supported by The Aluminum Association. This has generally better mechanical and tribological properties and is heat curable and weldable. Al 6063 alloy is the major regular alloy used for the aluminium extrusion. It allows the most compound shapes to be formed with extremely for flat-plane surfaces fit for anodizing and so it is well favorable for viewable architectural applications such as window mountings, doorway frames, ceilings, and sign boards. Applications requiring higher strength typically use 6061 [7-8].

Figure 1: *Pure Al-6063.*

Aluminum 6063 alloy was stir-cast with quarry gravel powder (QGP), abrasive silicon carbide (Sic) and fly ash (FA) particles of mass fraction percentage as reinforcement is fabricate Al 6063 hybrid composites. The chemical structure of Al 6063 alloy was show in Table 1. Quarry gravel powder (QGP) was collected from quarries and the Table 2 show the complete details of the chemical structural arrangement. The temperature of the inside and outside furnace was precisely monitored and perfectly controlled (±2°C) using advanced thermocouples and a PID controller. The experimental framework of stir casting equipment used a 0.25 HP motor is revolve the stirrer with blade at the several speeds in between 200 to 2000 rpm; a hydraulic elevater apparatus was utilize to guide the stirrer and help to move up and down moments in contact with composite material inside the furnace[9].

Table 1: *Chemical structural arrangement of Al-6063.*

Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
97.5	0.1	0.1	0.35	0.9	0.1	0.60	0.1	0.1

In this approach the stir casting procedure is used for fabrication of Al 6063 alloy with fraction reinforcement of 0%, 4%, 6%, 8% of quarry gravel powder (QGP), abrasive silicon carbide (Sic) and fly ash (FA) particles of weight percentage on aluminum 6063 is matrix material possess essential mechanical properties i.e high strength, fatigue strength, and ultimate tensile strength. It is used ask following application aircraft structure, automobile engines [10].

Table 2: *Chemical composition of quarry gravel powder.*

SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	TiO2
51	18.4	9.29	10.2	5.0	2.1	0.59	0.78

Figure 2: *Preheated quarry gravel powder.*

Figure 3: *Preheated fly ash preheated SIC.*

Figure 4: *Preheated fly ash preheated SIC.*

Table 3: *Chemical composition of SIC.*

Constituent	SiC	Si	SiO_2	Fe	Al	C
%Wt	98.5	0.3	0.5	0.03	0.1	0.3

Table 4: *Chemical composition of fly ash.*

SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	TiO2
49.5	25.54	1.03	0.47	0.65	6.13	8.92	0.53

Procedure for Stir Casting

A bottom pouring type fully sensorised stir casting machine is used to produce the AMMCs material. Initially the matrix material Al 6063 alloy cut bits placed into the 2 kg capacity furnace. The furnace temperature maintained was around 800-850 degree centigrade. The matrix material Al 6063 at above 750 degrees centigrade temperature material becomes at most liquid state. Then 10-12 grams of c2cl6 is added to degasifing the molten melt. And maintain organ environment with help of organ gas. Before stirring the reinforcement is preheated 250°C at 1 hour. The stirring was done by using mechanical stirrer and the stirrer speed was maintained 600 rpm and stirring time at 10 min. And it's stirrer is dipped 2/3 height of molten metal in the furnace.

During this stirring operation both matrix material Al 6063 and reinforcement material are mostly mixed. The die was preheated at most 450◦c at 60 min. finally the melted aluminium hybrid metal matrix composites was transferred into the permanent die.

Figure 5: *Stir casting machine and die with three finger composite piece.*

Processing Frame Work

Table 5: *Process parameters for stir casting.*

Parameters	Units	Values
Spindle rotation	Rpm	600
Stirring set time	Sec	480
Stirring temperature of the melt	ºC	750
Preheating temperature of quarry gravel powder- SiC & FA	ºC	250
Preheating time of the reinforcements	Minutes	60
Preheat temperature of die	ºC	450
Powder pouring rate	g/s	1.4

Test Conducted

- Tribological Evaluation (wear test)
- Micro Hardness
- Density

RESULTS AND DISCUSSION

Description for the Composites Generated

Table 6: *Samples designation.*

Samples selection	% Wt. (QGP:FLY ASH: SiCp)
0%	0
4%	50:25:25
6%	50:25:25
8%	50:25:25

Tribological Evaluation

Pin-on-disc technique equipment is utilized to assess the specific wear of materials during testing of the specimen's gliding surfaces. These trails were controlled under dried laboratory and normally non abrasive conditions according to ASTM standards. Schematic diagram of the pin-on-disc equipment is show in Fig. 8. The trails were conducted by applying basic loads of 15, 25, and 35 N and several sliding distances of 500, 750 and 1000m at several sliding velocity of 1.5 m/s respectively. The disc was made of the EN32 steel with a hardness of HRC 65. The MMHC samples were fabricated as bars with circular dimensions of 8 mm diameter with 35mm in height. The bars glide on the disk at a track radius of 60 mm, at the lower surfaces of test sample are plane and polished with metallographic alloy before testing. In order to maintain more precise values of the wear of material, each test was performed thrice for the end samples surfaces s polished.

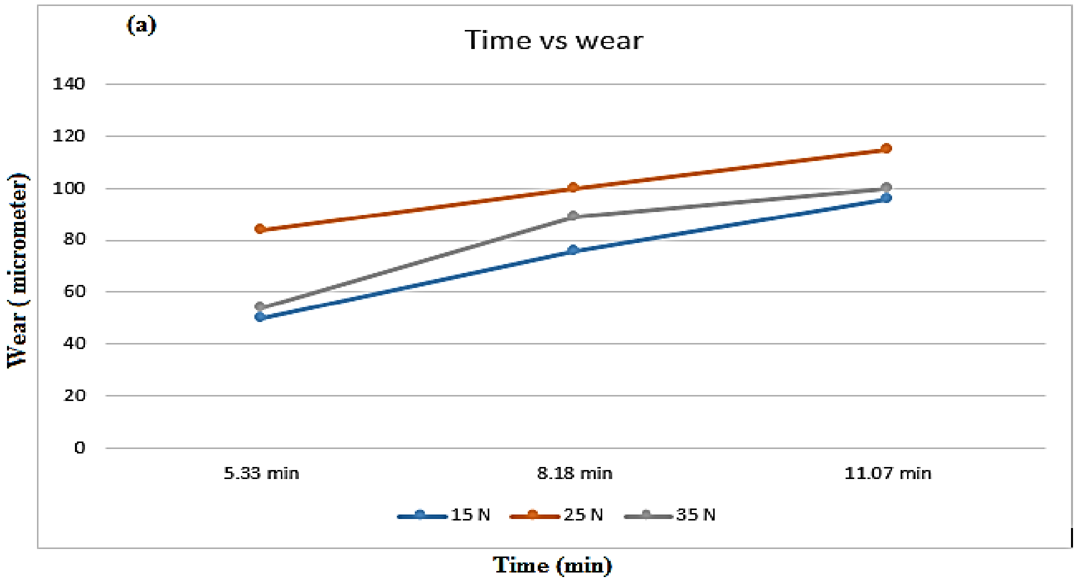
Figure 6: *Pin on disc set up.*

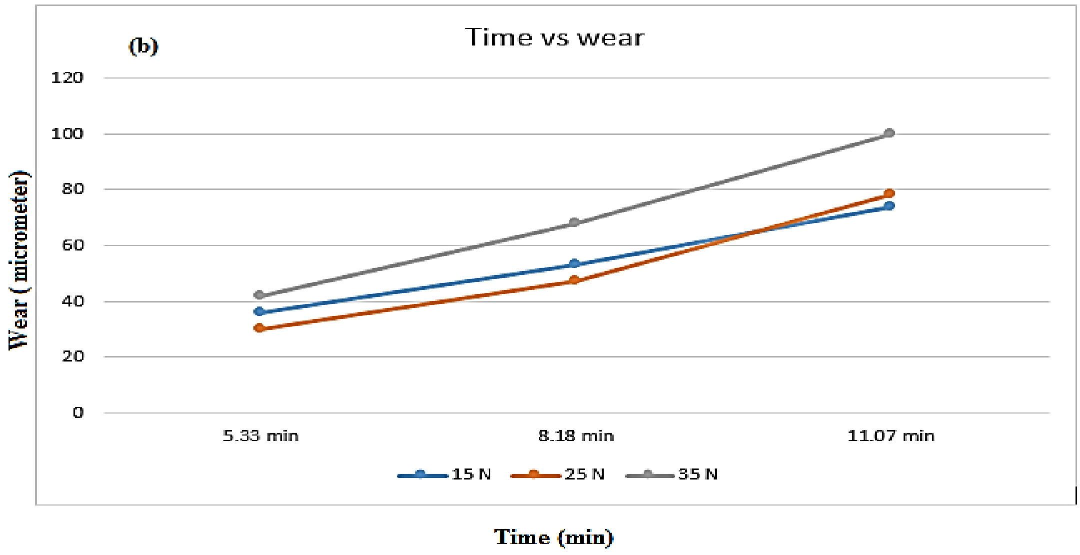
Figure 7: *Specimens for wear test.*

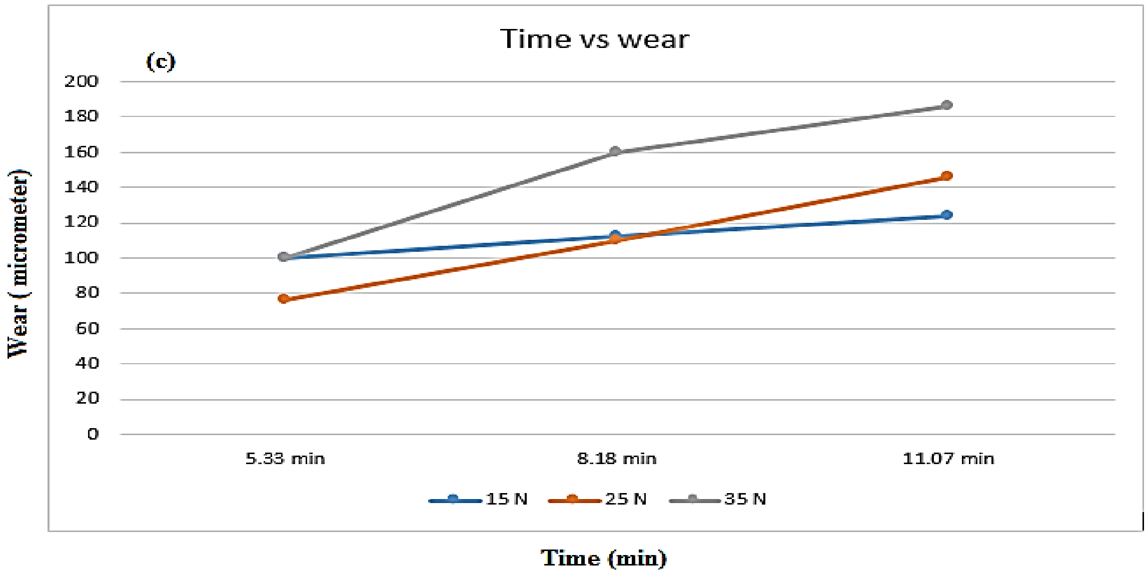
Specification of Wear Method
Track diameter = 60 mm
Sliding velocity = 1.5 m/s
Speed = 478 rpm
Reinforcement % = 0%, 4%, 6%, 8%
Sliding distances = 500, 750, 1000 m

Table 7: *Process parameters for wear.*

Reinforcement %	Load (N)	wear (micrometer)		
		5'33"	8'18"	11'7"
0%	15N	50	76	96
	25N	84	100	115
	35N	54	89	100
4%	15N	36	53	74
	25N	30	47	78
	35N	42	68	93
6%	15N	100	112	124
	25N	76	110	146
	35N	100	160	186
8%	15N	70	102	125
	25N	66	102	134
	35N	82	127	174


(a)
Time vs wear
Wear (micrometer)
140
120
100
80
60
40
20
0
5.33 min
8.18 min
11.07 min
15 N
25 N
35 N
Time (min)


(b)
Time vs wear
Wear (micrometer)
120
100
80
60
40
20
0
5.33 min
8.18 min
11.07 min
15 N
25 N
35 N
Time (min)


(c)
Time vs wear
Wear (micrometer)
200
180
160
140
120
100
80
60
40
20
0
5.33 min
8.18 min
11.07 min
15 N
25 N
35 N
Time (min)

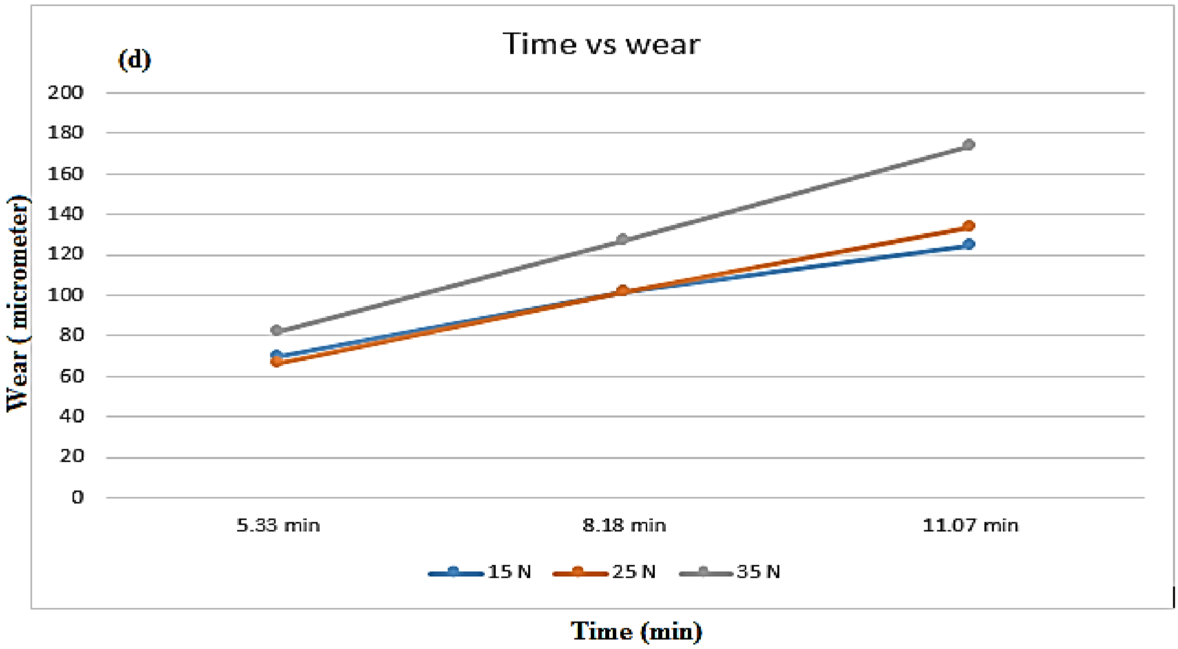


Figure 8: *Effect of wear of Al 6063/ (QGP: FLY ASH: SiCp) hybrid composite: (a) 0%, (b) 75µm, 4% (c) 75µm, 6% (d) 75µm, 8%.*

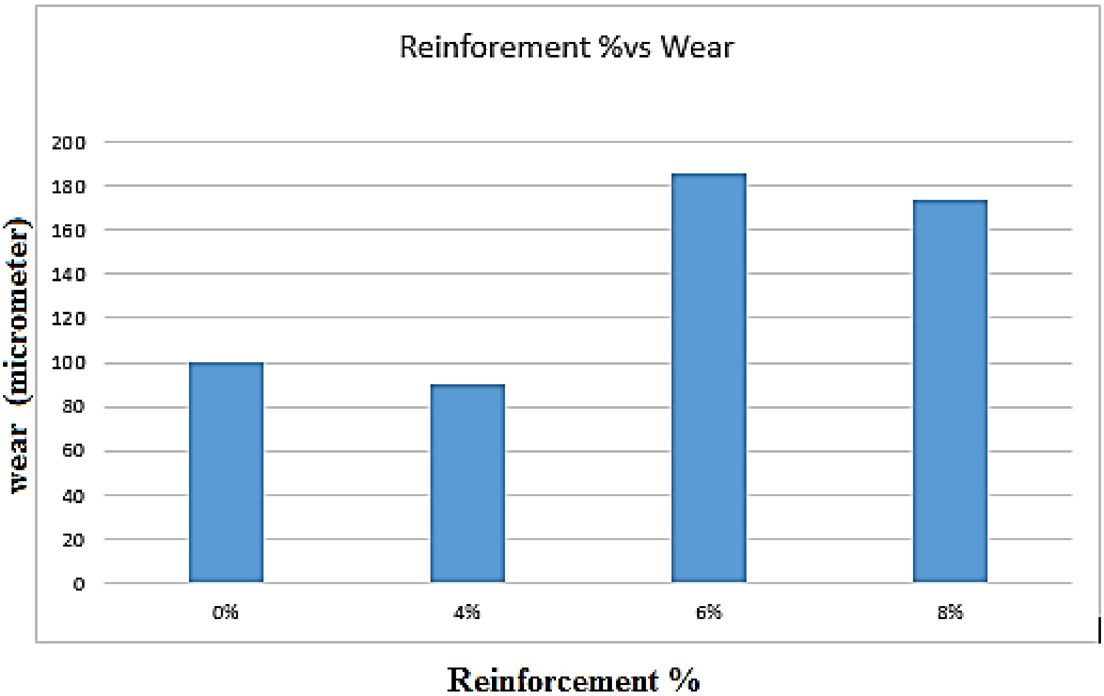


Figure 9: *Wear rate of Al 6063/ (QGP: FLY ASH: SiCp) hybrid composite.*

Micro Hardness

Mechanical properties of al 6063 hybrid composite such as hardness of the developed hybrid composites were determined by utilizing Vickers hardness apparatus with the scale of HRA. The sample fabrication and testing proceedings for the hardness measuring was convey with the following of ASTM E-8 standard in those samples was susceptable to a straight load of 100 grams for 10s; multiple hardness trails was supervised on each sample for accurate results and the average rate is taken as the micro hardness of the fabricated MMHC sample-pieces.

Figure 10: *Vickers hardness tester.*

Table 8: *Hardness of Al 6063/ (QGP: FLY ASH: SiCp) hybrid composite.*

Reinforcement %	Hardness(BHP)			
	Trail 1	Trail 2	Trail 3	Average
0%	74.45	46.67	88.47	69.36
4%	82.13	63.9	67.48	71.17
6%	31.39	87.22	111.5	76.70
8%	82.81	80.22	78.41	80.48

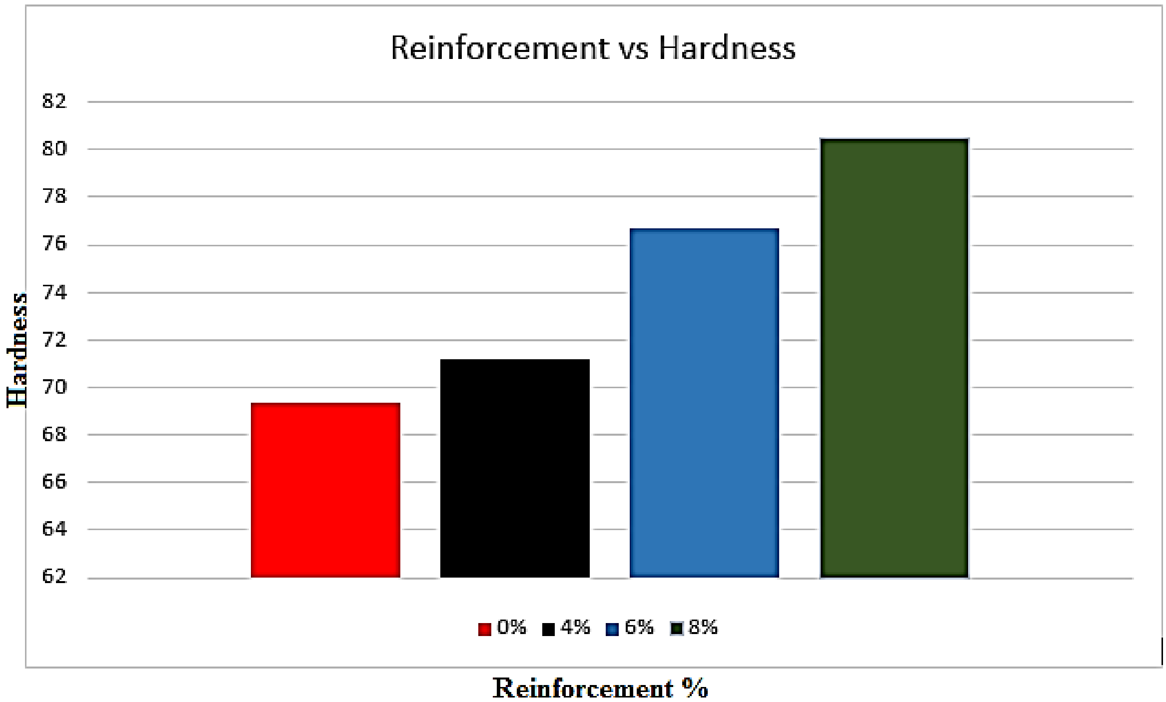


Figure 11: *Effect of hardness Al 6063/ (QGP: FLY ASH: SiCp) hybrid composite.*

Density

The density of the Al-6063 alloy based hybrid composite measurements was conveyed to the estimate the measure the porosity of the produced hybrid composites and in order to investigate the effect of the wt% portions of the quarry quarry gravel powder –fly ash-silicon carbide of the densities of the produced hybrid composites. This was attained by differentiate the experimental results to theoretical results of the densities of each composition of hybrid composite samples proportion weight percent of quarry gravel powder –abrasive silicon carbide reinforced hybrid composites using

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Journal of Advancements in Material Engineering
Volume 4 Issue 2

accepted procedures. The experimental density ($\boldsymbol{\rho}$EXT) were evaluated by dividing the measured weight of the hybrid composite sample by its measured volume.

The theoretical density ($\boldsymbol{\rho}$T) was obtained by using the methods of rule of mixtures. The percentage of porosity was evaluated by utilize the relations:

$$\% \text{ Porosity} = \frac{\rho\,\text{T} - \rho\,\text{EXT}}{\rho\,\text{T}} * 100$$

Table 9: *Density of Al 6063/ (QGP: FLY ASH: SiCp) hybrid composite.*

Sample Designation	Theoretical Density	Experimental Density	% Porosity
0%	2.86	2.77	3.14
4%	2.81	2.71	3.2
6%	2.54	2.4	2.16
8%	1.88	1.836	2.65

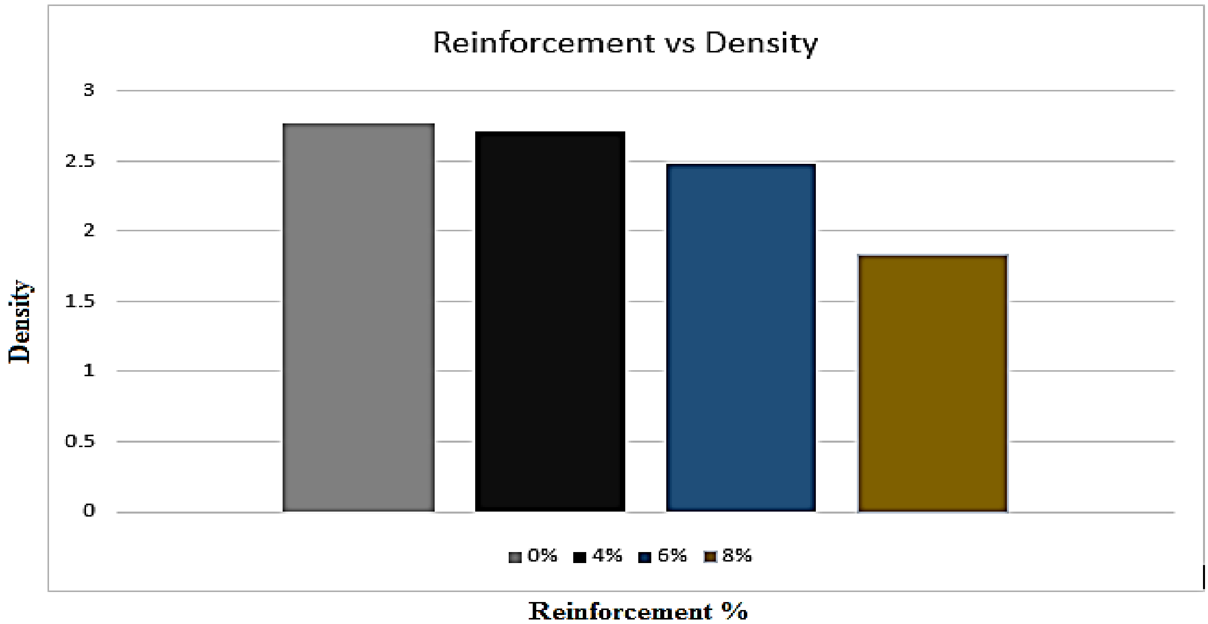

Figure 12: *Density of Al 6063/ (QGP: FLY ASH: SiCp) hybrid composite.*

CONCLUSIONS

The effect of quarry gravel powder-abrasive silicon carbide-fly ash mass fraction proportion of influence the mechanical properties and tribological wear rate of stir cast Al 6063 based hybrid composites containing 4wt%, 6wt%, and 8wt% versatile portions of quarry gravel powder (QGP), abrasive silicon carbide (SiCp) and fly ash respectively was studied. These results are shown that:

1. Quarry gravel powder easily available from the naturally formed quarry rock exhibit initiative potential as an attractive dispersoids to provide the lower cost-high performance of MMHCs.
2. The density of the hybrid composite gradually reduces for all 4 wt%, 6 wt% and 8 wt% reinforcement as quarry gravel powder-SIC-fly ash increases while there are significant changes in porosity.
3. The Vickers hardness of the hybrid Al 6063 alloy composite improves gradually with near to trend over to the parent base material Al 6063 alloy.
4. Hybrid composites containing 50% of quarry gravel powder and 50% of sic-fly ash for 4 wt% reinforcement shows superior wear (tribological) rate.

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Cite this article as:
Pamarthi Harish, Veeranki Mohan Srikanth, S.B.K Reddy, S.Srikatnh, & K Ch Kishore Kumar. (2019). Mechanical Properties and Triobological Behavior of Stir Cast Al-6063 Alloy Based Hybrid Composite. Journal of Advancements in Material Engineering, 4(2), 23–32. http://doi.org/10.5281/zenodo.3245759

