IMPROVING MECHANICAL PROPERTIES OF AL6061 METAL MATRIX COMPOSITE WITH CERAMICS AS AN REINFORCEMENT

Bestha Venkatesh[1], Dr. K. Kalyani Radha[2]M.Tech,Ph.D.

[1]PG Scholar, Department of Mechanical Engineering, Jawaharlal Nehru Technological University, Anantapuramu, India [2]Assistant Professor, Department of Mechanical Engineering, Jawaharlal Nehru Technological University, Anantapuramu, India

Abstract

Aluminum 6061-based metal –matrix composites (MMCs) have received considerable attention for automobile and industrial sector applications because of their low density and high stiffness. Improvement in fuel consumption rate requires a reduction in vehicle weight. Research and development for materials substitution in the braking system, from the conventional cast iron to aluminum, has been undertaken. A composite material is a material system composed of a suitably arranged mixture or combination of two or more nano, micro, or macro constituents with an interface separating them that differ in form and chemical composition and are essentially insoluble in each other. They have characteristics like high strength to weight ration, hardness and wear resistance. In the present investigation, an AL6061 alloy is using as the matrix and ceramic as the reinforcement. The composite is fabricated using stir casting technique. Aluminum composites are a new generation of metal matrix composites that have the potentials of satisfying the recent demands of advanced engineering applications .These demands are met due to improving mechanical properties, amenability to conventional processing technique and possibility of reducing production cost of aluminum composites. The casting components are machining to specimen dimensions and are subjecting to various material testing and finding the mechanical properties. In different weight fraction of ceramic reinforced materials. By conducting various material testing's like Scanning Electron Microscopy (SEM). Pin-on-disc test. The results will shows the better mechanical properties compared existing.

Keywords: Al-6061, Stir Casting, Wear Behavior, UTM, SEM Analysis, pin-on-disc test, EDS

1. INTRODUCTION:

Aluminum Metal Matrix Composites (AMMC's) provides huge fulfillment of applications on the pure metals and metallic alloys. The main properties of AMMC gave them too many advantages in the areas such as aircraft, automobile and sporting goods industries. AMMC's are mainly classified into three types that are based on reinforcement; namely particulate reinforced, discrete fiber reinforced and Continuous fiber rein-forced AMMC's. Among all of these, Particulates of AMMC's have become very crucial due to their application of light in weight, therefore they are employed in automotive and aerospace manufacturing industries. Use of composites beyond the conventional materials like steel, usually provides major weight savings. Due to the specific properties and low weight, it is possible to manufacture composite materials for special purposes. For example, a composite material will be designed specifically for a particular type of load. It is highly advantageous over conventional materials due to the resistance to chemical, thermal and electrical insulation properties.

2. MATERIALS:

Aluminum alloy Al-6061 have an enormous engineering uses including in construction and transportation where the desired thermal & mechanical properties are required like wear UTS, conductivity etc. they are mainly suitable for automotive industrial applications, because of its highly corrosive resistance. The Chemical composition of Al6061 is mentioned in the tabular column given below.

Table 1. Chemical Composition of Pure Al-6061 alloy

Element	si	mg	Fe	Mn	Cu	V	Ti	Al
Weight %	0.64	0.64	0.18	0.53	0.3	0.01	0.02	Remaining

Al-6061 is a precipitated–hard aluminum alloy, containing silicon and magnesium has major Si alloying components and is originally called as "Alloy 61S". The Alloy 61S is developed in a year 1935.[2] It have good mechanical properties, which exhibits weld ability and it is very commonly used. In general, it was one of most widely using Aluminum alloy among in all of this series.

Table 2. Properties of Al-6061

Physical Properties	Density 2.700 gm/cm^3			
Mechanical Properties	Modulus of Elasticity (E)	UTS	Elongation	Poisson's ratio
	68.8 GPa	125 - 290 MPa	12 - 24 %	0.34
Thermal Properties	Melting tem-Perature 584 ^0C	Thermal conductivity $2.24*10^{-5}$ K^{-1}	Thermal expansion 896 J/Kg K	Specific heat capaci-Ty 32.5–38.2 ohm*m

The only chemical compound of silicon and carbon is SiC. The Process for Production of SiC, by high temperature of electro chemical reaction of carbon and sand. It have better abrasive and has been produced and made under grinding wheels. Presently it is consider as high functional graded ceramic due to its excellent mechanical properties for technically, shown in the below tabular column.

Table 3. Mechanical Properties of SiC

Density	3.1 gm/cc
Ultimate Tensile Strength	162.5 MPa
Young's Modulus	137 GPa
Brinell Hardness	2800 kg/mm
Poisson's Ratio	0.37
Thermal Conductivity	3.80-20.60 W/m K
Melting Point	1682 °C

Graphite is made from of carbon under standard conditions and it can also be used as a solid lubricant. It is quite a good conductor of electricity, due to the delocalized electrons that are free to move throughout the graphite layers under the influence of an applied electric field. Natural Graphite is mostly uses in what are called Refractory applications. The particle size of the graphite used in research is 16 microns. Particle size influences the wear properties of composites remarkably. Stability of oxidation and highly corrosive resistance.

It is most attractive material for the Al industry as substance due to refinement of grain size when casting aluminum alloys, because of its extensive properties like Wettability, Low solubility and Electrical conductivity. It can be used as a cladding for better wear and corrosive resistance. Presently it is consider as high functional graded ceramic due to its excellent mechanical properties for technically, shown in the below tabular column.

Table 4. Mechanical Properties of Graphite

Density	2.49 gm/cm^3
Ultimate Tensile Strength	76.9 MPa
Young's Modulus	27.6 GPa
Brinell Hardness	326 Mpa
Poission's Ratio	0.23
Thermal conductivity	114 W/m K
Melting Point	3970 ^0C

3. METHODOLOGY:

Al-6061 have taken in a chemical composition shown in Table 1. It will be melted in the resistance furnace. The crucible is made of graphite. Previously fabrication of composite, melting losses of a alloy constituents are taken into a consideration. The composite will fluxed with coverall the prevent dressing. The molten liquid alloy was degasified using tetrachlorethane. The crucible is modified with the sodium is taken out of the furnace. The molten liquid of matrix is in the form of semi solid state, by cooling down to, below the liquidous temperature. During this process, the molten liquid is added by the pre-heated reinforcements (which is 470^0C for ½ hour) SiC & Graphite particulates. The volume friction are SiC & Graphite (3% of graphite +sic),(5%of graphite +sic)(7% of graphite +sic)in my experiment sic is constant with(1%) . The average size SiC & Graphite is 10µm & 16µm. Molten SiC and Al6061 particles are stirred manually at regular inter-vals. After sufficient stirring manually over a period of time, semi-solid state of liquid is reheated to a fully liquid state in resistance furnace, simultaneously an automatic mechanical stirring is also carried out for about 15 minutes at 600 rpm to turn the liquid into homogeneous mixture. Using a thermocouple which is of dipping type, temperature is measured. Finally, after attaining a proper mixing of matrix & reinforcement, it is poured into the preheated cast iron mould in presence of gravity.

Fig.1. Photograph of Composite Material Al6061+SiC & Graphite

4. EXPERIMENTATION:

4.1 MICROSTRUCTURE

To study the microstructure of fabricated composites, standard metallographic procedure is followed & the samples are prepared. Samples are grinded and then polished by surface grinder and emery paper respectively. Mirror finish is obtained by polished with alumina powder. Keller's reagent is applied to the samples and then their microstructure is investigated by the help of Scanning Electron Microscope (SEM) [11

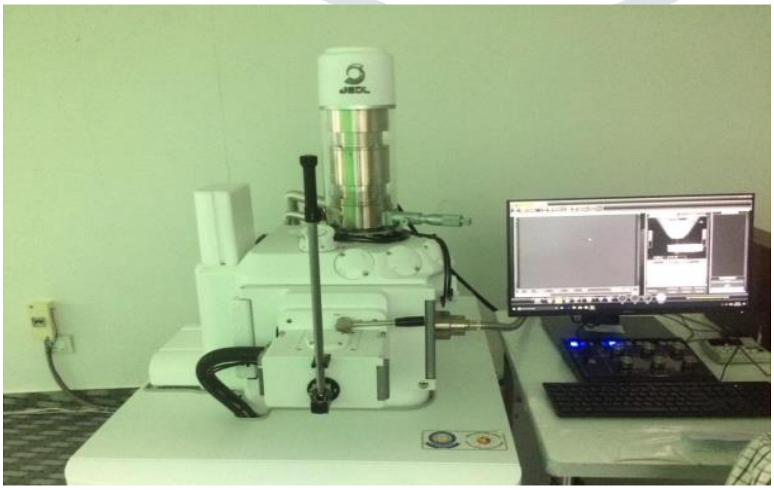


Fig.2. Photograph of SEM Analysis Equipment

4.2 TRIBOLOGICAL TEST:

From the literature, it is observed that the wear and friction behavior of MMC`s having Aluminum as matrix strongly depends on the particles used for reinforcement. Its size and volume fraction of particles. The coefficient of friction from the metal matrix composites are high if rate of reinforcement particle is low and besides this, the wear resistance increases with increasing volume fraction of reinforcing particulates. If the particulates used for reinforcement bounded well to the matrix, the wear resistance of the composite increases continuously with increase in the volume fraction of ceramic particles and the critical volume fraction mostly depends on the load applied during the wear test.

Fig.3. Pin on Disc Equipment

Al6061+SiC & Graphite composites are made as per the ASTM (American society for testing and materials) E8 standard for studying of wear analysis, under constant load condition. In this study, a flattened specimens of length 30 mm having dia of 8 mm are made. The tracking radius of pin on the disc, which slides is about 60 mm. to get a fully contact of specimen with a disc, which is rotating, should be pressed against a rotating EN31 carbon steel disc having 65 HRC, by loading with a known weights. Each specimen is polished by alumina powder & the rotating disc is by 4000 emery paper before going for test. Wear resistance under dry sliding condition test are carried out on each cast compo-site specimens by applying a constant load of 10N-force & sliding distance of 848 mts at a velocity of 2.82 mts/sec. The test duration is about 300 sec at a constant velocity of disc, having 900 RPM. Wear rate, frictional force & Co-efficient of friction vs sliding distance analysis is carried on each specimen.

4.3 UTM (TENSILE STRENGTH):

By means of ZWICK Z100 testing machine one can exercise static tensile tests of any materials at room temperature as well as temperature elevated to 1200oC.The machine is equipped with tools facilitating strength tests of round samples, screwed, of grip head diameter M8 to M16 and flat of thickness up to 8mm. Use of two furnaces for heating samples allows to increase the efficiency of tests by 50%. Testing stand makes it possible to monitor continuously the temperature in the furnace and on the surface of the sample by means of six thermocouples and temperature controller: universal 3-Zone Furnace Controller, Model ME44-180. Use of ceramic extensometer: Zwick –clip-on WN: 19 extensometer facilitates execution of direct measurement of change in the length of sample during sensitive phases of tensile test.

Fig.3. Tensile test equipment

Basic scope of offered tests by means of Zwick Z100 machine for tests at elevated temperature.

5. RESULTS AND DISCUSSION:

5.1 MICRO STRUCTURAL ANALYSIS:

The samples of metallographic were sectioned from the Cylindrical cast composites to observe the difference of distribution of Sic & Graphite particulates in the Al-6061 matrix, for these samples etching are done whenever required by the help of 0.5 % HF solution and is observed for any developments under EVO® HD Scanning Electron Microscope from Carl Zeiss**.** All the samples were cast composites which are having different weight fractions (3%, 5% & 7% of Sic & Graphite) as a reinforcement.

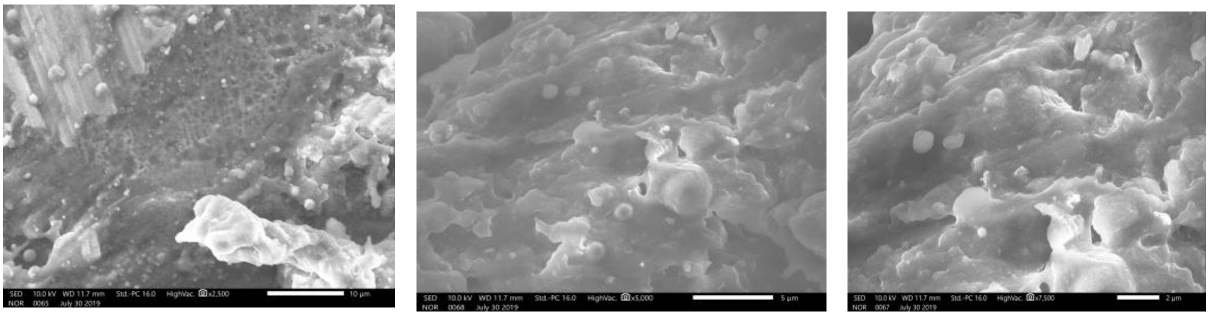


Fig.4. Micrograph of Al6061+3% of SiC & Graphite with 2.5KX, 5KX & 7.5KX

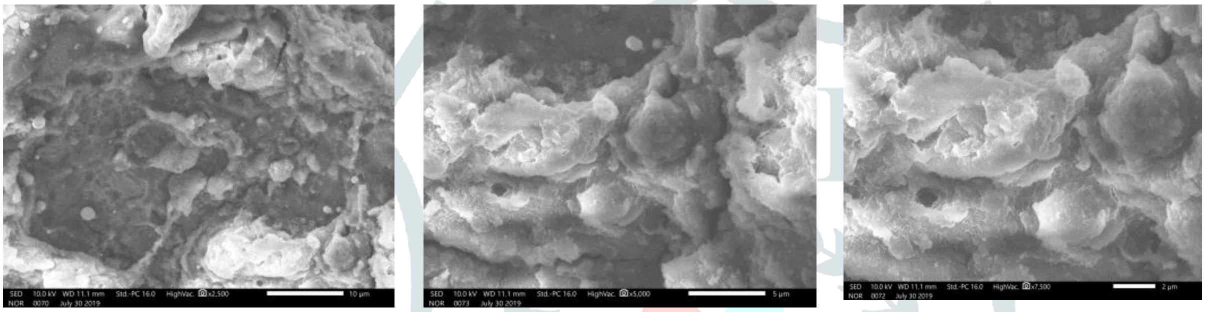


Fig.5. Micrograph of Al6061+5% of SiC & Graphite with 2.5KX, 5KX & 7.5KX

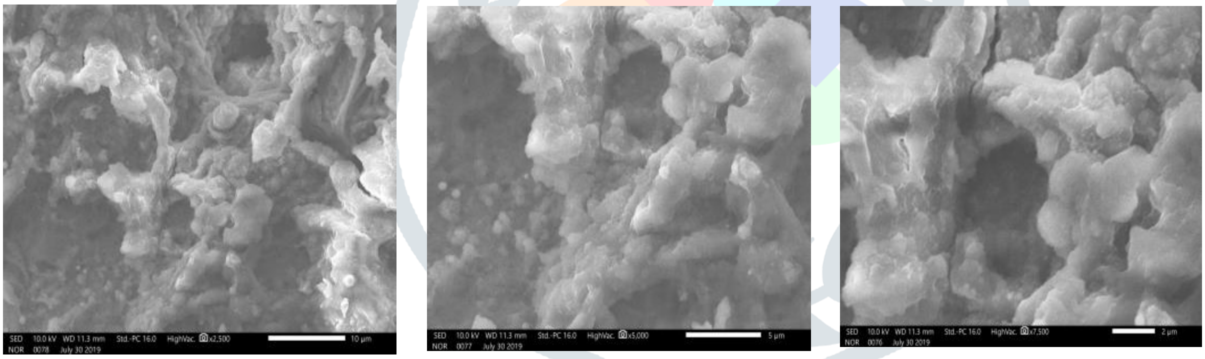


Fig.6. Micrograph of Al6061+7% of SiC & Graphite with 2.5KX, 5KX & 7.5KX

Second step mixing is needed to improve the particle distribution i.e., slurry is heated above the liquidus temperature and then stirred well for 15 minutes at 600 rpm using an Automatic stirring device.

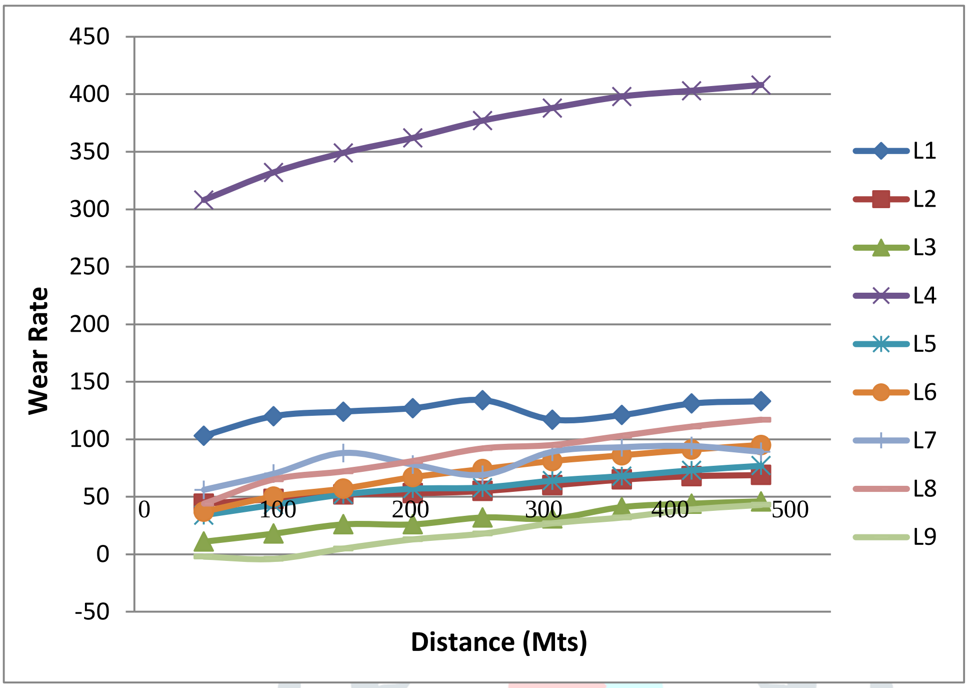
As observed from Fig 4. That the cast composite which is having a wt proportion (3% of SiC) as reinforcement, particle cluster & absence of SiC at different locations. Particulates which are added to the molten alloy, were observe on the top layer of molten surface, though they have a more value of specific density than the molten alloy. Having Higher Surface tension and poor wetting properties, makes it to float on the surface. Wettability between the ceramics and molten liquid alloy is poor & its improvement is by applying mechanical force on the particles, by overcoming the surface tension.

From figures 5 & 6, it revealed that microstructure of specimens having Wt proportion (as reinforcement. It clearly observed that the resulting of cluster formation & non uniform distribution of particulates in the samples.

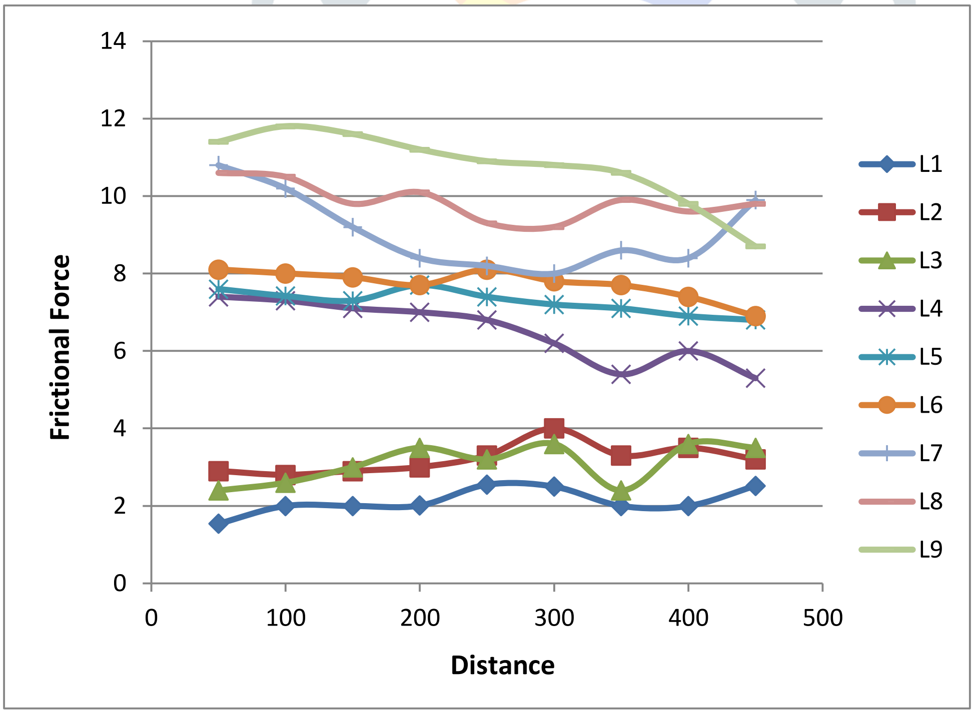
5.2 WEAR ANALYSIS:

In order to observe the qualitative proof on the particulate distribution in the matrix, among the two ceramic reinforcements (Sic & TiB2) Wear rate is to be employed. On Wear resistance testing machine, which is under dry sliding condition, testing were conducted at ambient temperature, and the specimens are loaded against the rotating disc by applying the known weights. The graphs that are obtained by the experimentation would reveal the Co-efficient of friction, Frictional force & wear rate of fabricated composites.

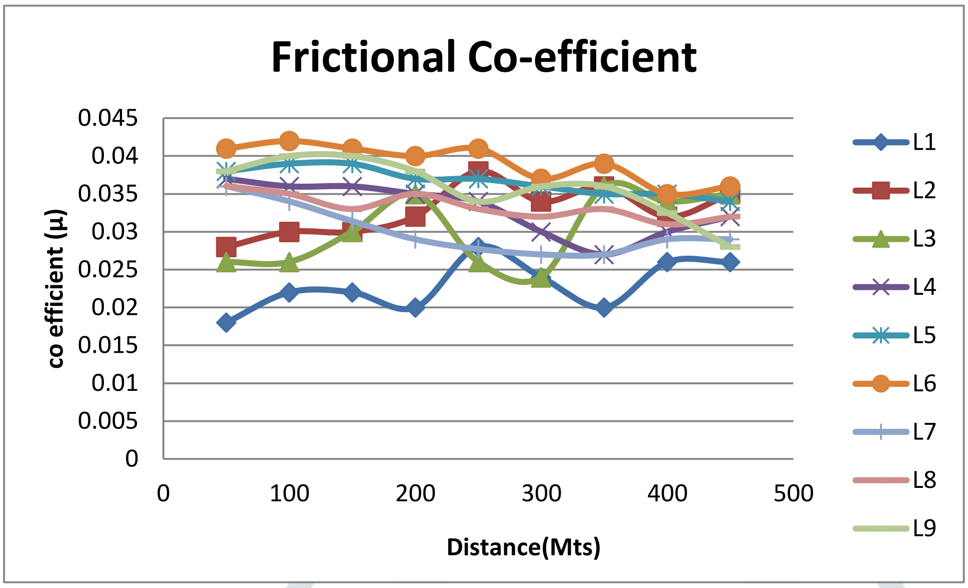
Graph 1. Wear rate v/s Sliding Distance of Cast composites



Graph 2. Frictional force v/s Sliding Distance of Cast composites



Graph 3 Frictional coefficient & Sliding Distance of Cast composites

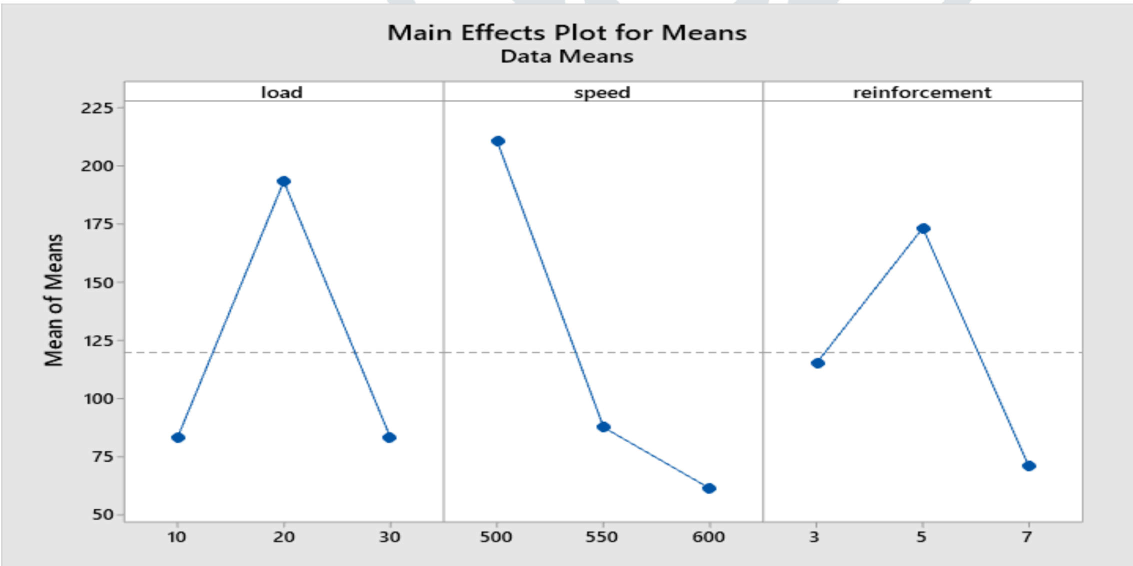


The wear rate of all specimens (mm^3/Nm) is obtained and are plotted against the sliding distance, as shown in the Graph 1. For a constant load of 10 N-force for different reinforcement of SiC and Graphite (3%, 5% & 7%). In Graph 2, it is reveals that at constant load application, wear rate increases, against the sliding distance of all the specimens, A special characteristics were observed in Graph 2. That Al6061+7% of SiC has less wear rate among all cast composites, having maximum of $64mm^3/m$ at a sliding distance of 848 mts.

The frictional force of the specimens will give frictional coefficient values directly, & are plotted against the sliding distance as shown in the Graphs 2&3 for a constant load of 10 N for different % by wt. proportion of reinforcement SiC & graphite. From the Graphs 3&4, it is shown that coefficient of friction & frictional forces were drastic changes in the cast composites of Graphite as a reinforcement because of non-uniform distribution of particulates in the matrix. It was observed that, Al6061+7% of SiC has more frictional force & Co-efficient of friction among all cast composites, having maximum of 3.5N & 0.035 respectively over a sliding distance of 848 mts.

5.3 TAGUCHI ANALYSIS:

MINI TAB 18 STATISTICAL SOFTWARE:

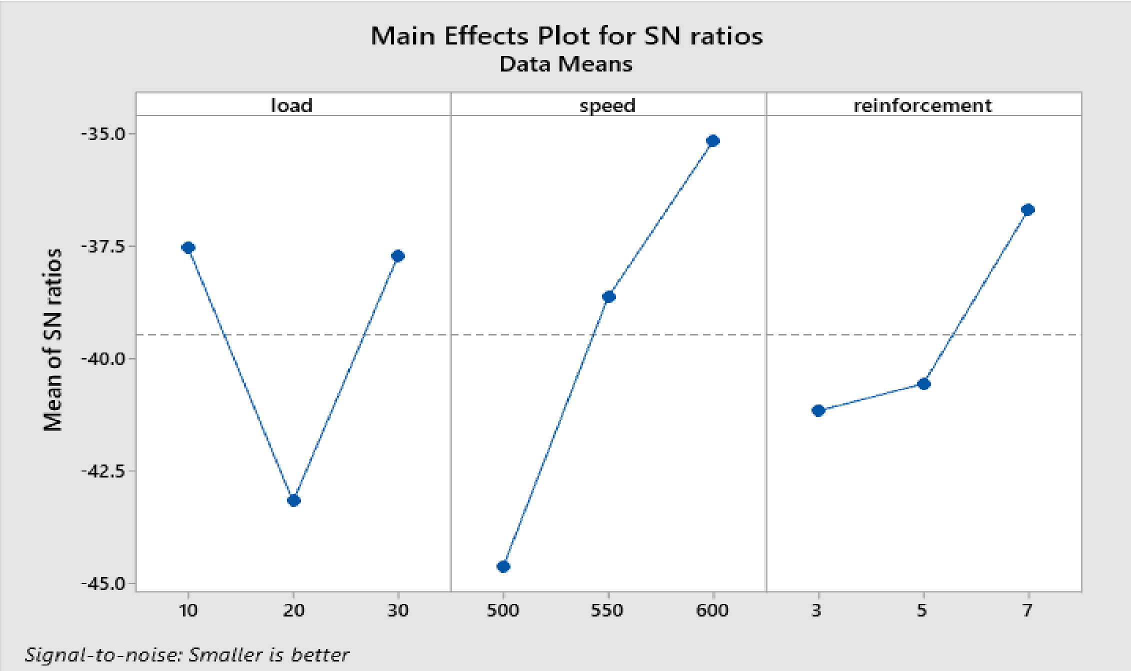


Graph: 4.1: PLOT FOR MEANS

Response Table for Means

Level	load	speed	reinforcement
1	83.00	210.67	115.33
2	193.33	87.67	173.33
3	83.33	61.33	71.00
Delta	110.33	149.33	102.33
Rank	2	1	3

Speed has more influences than load, load has more influences than reinforcement.



Graph: 4.2: PLOT FOR SN RATIOS

Response Table for Signal to Noise Ratios

Smaller is better

Level	Load	speed	reinforcement
1	-37.52	-44.61	-41.15
2	-43.17	-38.62	-40.55
3	-37.71	-35.16	-36.69
Delta	5.64	9.45	4.46
Rank	2	1	3

Speed has more influences than load, load has more influences than reinforcement.

5.3 TENSILE STRENGTH ANALYSIS:

In this test conducted different testing standards like strain rate 10^{-3}, ambient temperature and no pre loaded**,** why because our testing material is composite not pure material.

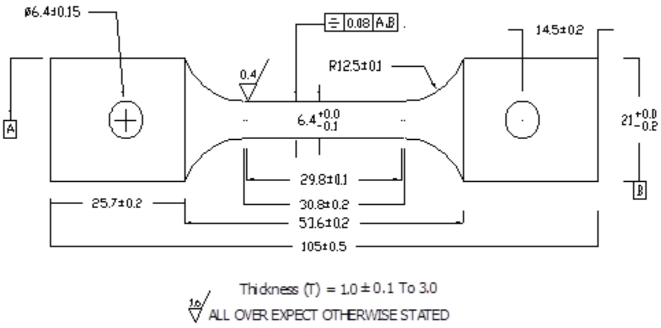
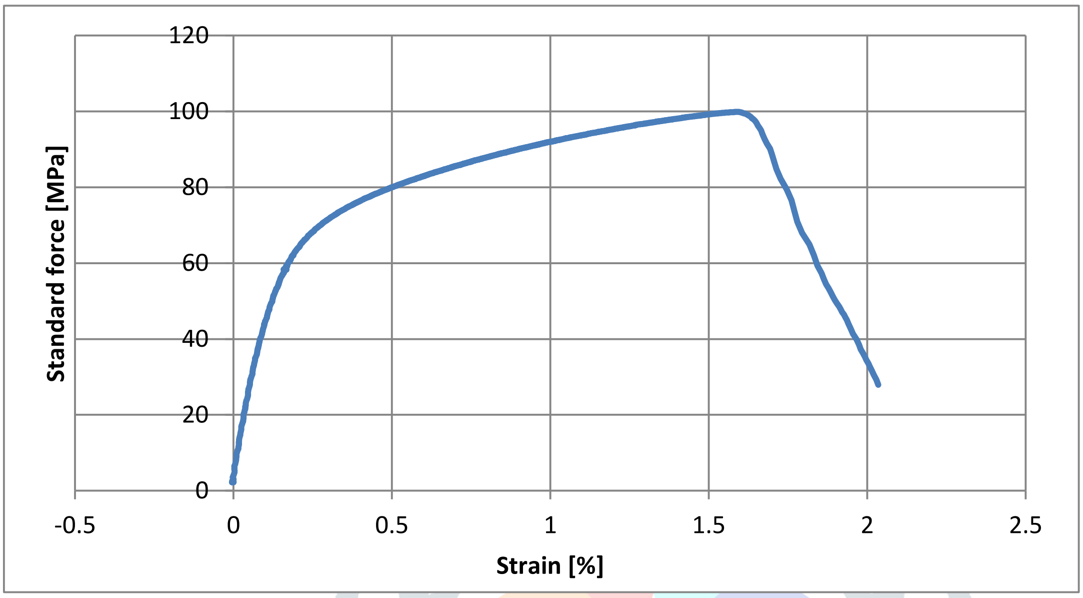


Fig.3. standard tensile testing specimen's dimensions



Graph: 4.2: PLOT FOR 7% REINFORCEMENT SPECIMEN

Column1	m_E	$R_{p0.2}$	R_{eH}	E	R_m	A_g	A_{gt}	R_B	A_{30mm}	A_t	a_0	b_0	S_0
	GPa	MPa	MPa	GPa	MPa	%	%	MPa	%	%	mm	mm	mm^2
3	17.82608	88.81032		68	102.8026	0.723652	1.086587	97.55624	0.821875	1.155379	4.11	6.41	26.3451
5	5.800845	83.0784	83.3004	34	83.3004	0.222627	0.947822	16.54582	2.008178	1.582599	3.99	6.43	25.6557
7	9.96824	84.77356		28	99.86667	0.969328	1.589721	27.94198	2.136246	2.0351	4	6.46	25.84

Table 5. For all three specimens

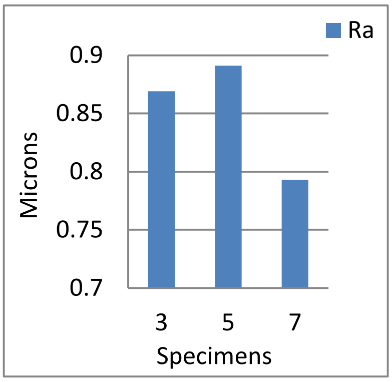
From the table 5, it shows that yield strength has reduced to 18% when compared with 3%&5%

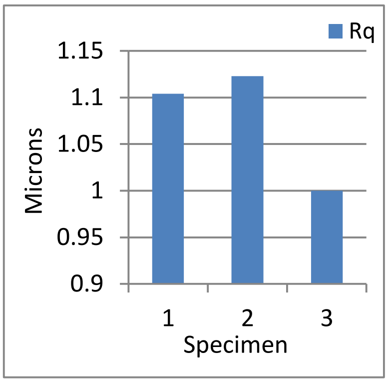
While when compared 3% & 7%, it is reduced to 2%

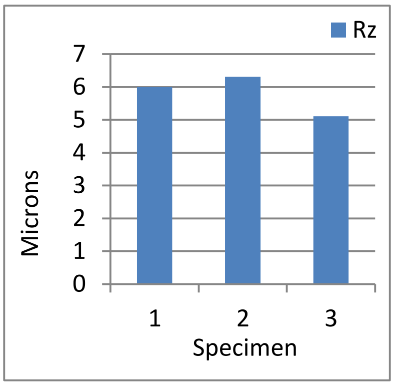
Based on the total strain value, 7%has a good toughness when compared with 3% & 5%.

5.4. SURFACE ROUGHNESS:

Testing have been conducted on all the specimens, with different weight fraction of SiC and Graphite (3%, 5% & 7%) as a reinforcement in Al-6061 which are fabricated by stir casting. Hardness are Recorded and graph is plotted for the obtained values.







Graph: 5.1 **Graph: 5.2** **Graph: 5.3**

Ra = Mean Roughness
Rq = Root Mean Square
Rz = Roughness Depth

The results as indicated in graphs, shows that surface roughness is having low at 7% SiC &graphite

Here experimental study reveals that:

1. As per the taguchi L9 experimentation, for different % by wt proportion of reinforcement of SiC & Graphite particle with Al-6061 as a matrix, SiC+graphite (7%) by wt would have maximum frictional force & Co-efficient of friction & minimum wear rate.
2. The best results have been obtained at Track Dia=55, Load=10N, Speed=600rpm, and reinforcement=7% by wt. proportion of SiC as a reinforcement
3. For conformation Taguchi analysis &linear regression equation are used in minitab. It is confirmed that L_3 have optimum parameters
4. The formation of cluster is observed in when 3% siC+graptie` used as reinforcement in the Al6061 matrix which are observed in SEM photograph,
5. The hardness value is higher, due to 7% of SiC+Graphite as a reinforcement, with homogenous distribution of particles as shown in EDS report.
6. The EDS shows major elements (Al, SiC, Mg, C) %of weight in all samples (3 5 7) reinforcement
7. The surface roughness is more for the specimen having 3% reinforcement.
8. From the UTM test, If reveals that 7 %(sic+graphite)would have good strength of tensile.

6 CONCLUSIONS:

From the above results, we conclude that by an experimental investigation with different weight proportions of Hybrid Metal Matrix composites (3%, 5%, 7%), A better mechanical properties was observed in 7% (6+1) reinforcement among 3% and 5% .

6. REFERENCES:

1. Manoj Singla1, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla, " Devel-opment of Aluminium Based Silicon Carbide Particulate Metal Matrix Com-posite", Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467, 2009.

2. S A Mohan Krishna, T N Shridhar et al, " Research Significance, Applica-tions And Fabrication Of Hybrid Metal Matrix Composites", IJISET - Inter-national Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 5, May 2015.

3. Ashok Kumar Mishra, Rajesh Kumar Srivastava, "Wear Behaviour of Al-6061/SiC Metal Matrix Composites", springer, DOI 10.1007/s40032-016-0284-3

4. G. Srinivas Kumar, V. Viswanath Chari, " Comparison of Mechanical characterization of Al metal matrix composite and Gray Cast iron of an automo-bile brake rotor", International Journal of Engineering Innovation & Re-search,Volume 6, Issue 5, (September) ICEMS-2017, ISSN (Online) : 2277 – 5668.

"Selection and Applications" – The Aluminum Association, Inc. Dec-1998.

6. S. Ghosh • P. Sahoo • G. Sutradhar, "Tribological Properties of Al–SiC Met-al Matrix Composites:A Comparison Between Sand Cast and Squeeze Cast Techniques", J. Inst. Eng. India Ser. D (July–December 2014) 95(2):161– 171.

7. Narendra Kumar1,4 . Gaurav Gautam et al, "Synthesis and Characterization of TiB2 Reinforced Aluminum Matrix Composites: A Review", J. Inst. Eng. India Ser. D, Aug-2015.

8. Hiroaki Nakanishia, Kenji Kakihara et al, "Development of aluminum metal matrix composites (Al-MMC)brake rotor and pad", JSAE Review 23 (2002) 365–370.

9. Gaurav Mahajan *, Nikhil Karve , Uday Patil , P. Kuppan , K. Venkatesan. "Analysis of Microstructure, Hardness and Wear of Al-SiC-TiB2 Hybrid Metal Matrix Composite, IJST, Vol 8, suppl-2, Jan-2015.

10 .V. VIswanatha Chari ,G.Srinivas Kumar," Fabrication &Testing of Reinforced composites of carbon and Agave Fibers",IJWIR,vol 6,sep-2017

11."Optimization of process parameters in turning of aluminum metal matrix Composites"k.Ramadevi,,B.D .Sai Chaitanya Kishore,IRJET,vol6,july-2017