Characterization of Mechanical and Tribological Properties of Aluminium alloy based Hybrid Composites Reinforced with Cotton Shell Ash and Silicon Carbide

Pamarthi Harish[1], Veeranki Mohan Srikanth[2], P Ravindra Babu[3], M. R. Ch. Sastry[4], KCh Kishore Kumar[5]

[1] PG student,[2] Assistant professor, [3]Professor & Principal, [4] Professor &Hod, [5] Associate professor
[12345]Department of Mechanical Engineering, Gudlavalleru Engineering College,Gudlavalleru-521356

Abstract

Al-6063 alloy is used as a matrix material and agro waste of cotton shell(CSA) ash and silicon carbide(SIC) is used as hybrid-reinforcement with a percentage of 0 wt%,1 wt%, 2 wt%and 3% by using stir casting methodology. The hybrid-composites (HC) are fabricated by thereinforcement with 75 μm. The hybrid-composite accommodate with the 1wt%, 3wt% and 3 wt% CSA-SIC with percentage(%) of 3:1 respectively thoseareproduced by the bottom pouring stir-casting method.The fabricated hybrid composite is supervise various tests to evaluate the mechanical properties like lower-density, porosity, hardness and wear behavior was observed and analyze the process parameters and their influence ofcotton shell ashThe particle size,surface structure, grain-structural boundaries have been investigatingwith Trinocular metallurgical microscope the help of computerized inverted metallurgical microscope. Effect of CSA-SIC as a reinforcement of particular emphasis the result were compared with basic matrix material.

Keywords
AL_6063, hybrid composite, cotton shell ash(CSA), silicon carbide(SIC), Stir Casting methodology, wear, micro hardness, density, micro-structure.

1. Introduction

Material is whateverbuild of matter, constituted of one or other mediums. Timber, cement, hydrogen, air and water those all are examples of defined materials.standered monolithic materials possesrestritionsto reach the combination of good strength, better stiffness, firmness and lowerdensity etc. To beatthose shortcomings and to encounter the ever rising demand of current day technology, composite materials are biggest favourable materials of presenrt interest. Metal matrix hybrid composites (MMHCs) possess significantly enhacne properties incorporate high strength; specific modulus, damping factor and better wear resistance compared to un-reinforced alloys. Those areimproving interest in composite materials accommodateAluminum Metal Matrix Composite (AMMC) provide designers more added benefits, those are particularly fitt for necessity application of good-strength, good structuralrigidity, dimensional stifness and lightweight. AMMCs provide enhance the properties like over the monolithic alloys. Composite materials are one in which the individual components regain their own individual characteristics but are incorporated into composite material so as to shows those advantages and not their shortcomings, in orderly to procure an upgraded materials. The requirements for composites has becomes a necessity for modern technology, due to the better physical and mechanical properties. Lower-density and low-cost reinforcements.The metal matrix hybrid composites(MMHC) has high-level of mechanical properties whendifferentiate to the standred materials. The dimensional firmness, good strength, high severity, better wear behaviour etc make themaccessible for substantial range of engineering applications. Quarry dust, fly ash, ceramics, E-wates, ocean wastes and agricultural waste ashes are waste materials which are available abundantly in the current world. Simultaneously Aluminum metal matrix hybrid composites (Al MMHCs) are utilizing overall in numerous structurized and tribologicalapplications.Major of the aerospacis spare parts implementations, titanium-alloys have been adapted by aluminum alloys.

Aluminium metal matrix hybrid composites(AMMHC) reinforced withfly-ash and abrasive silicon-carbidby utilize standred methods shows increasing trend over many properties of themare increase in reinforcementportion, other than the density will reduces with the increase in the reinforcementportion. Present approach concentrate both them experimental and analytical studies of Al-MMHCs forsuperior mechanical properties and fine wear behaviour. Improvements of mechanical and tribological behavourdepends majorly on fabrication methodologies like powder-metallurgy method, friction stir technique, bottom pouring stir-casting and squeeze-casting to fabricate particulate reinforced Al-MMHCs. Based on literatureservey of the above methods, bottom pouring stir casting technique was supposed to be the safest, easiest and the most economical proedure for fabricating particulate reinforced AL-MMHCs.

The performance of AL-MMHCs described by the tribological response such as wear behaviour and coefficient of friction are the procure factors. The wear and friction properties of Al-MMHCs use to obtained by pin-on-disc tester. In this test, pins of Al-MMHCs slide to against EN32 hard steel disc or cast iron disc under various loads. The results obey that the incresingabrasive SiC, reduces the wear rate. Whereas coefficient of friction increases with increasing of SiC. Wear behaviour of the composite materials differs by means of the applied load and sliding velocity.Increase in sliding speed and load leads the wear rate improves. Addition of reinforcement to aluminum matrix alloys to increases the wear resistance of composite material

2. Expermental procedure

2.1 Materials and methods

The AL_6063 is an aluminium established alloy, in this major proportions are the magnesium and silicon are the main alloying elements. The regular grademanagement ofthe composition is supposed by the Aluminum alloy Association. It has generally superior mechanical and tribologcial properties and is heat-curable and weldable. Al-6063 alloy is the major regulargrade standardalloy utilize for the aluminium extrusions. It’s allow the most aggregate shapes to be formed with extremely for flat-plate surfaces fit for anodizing and so it is well favorable for viewable architectural applications like window mounting, doorways frames, ceiling fittings, and sign board applications.

Fig: 1Al-6063 alloy

Aluminium alloy 6063 was stir-casted with the cotton shell ash (CSA) and silicon-carbide (Sic) particles of weight fraction% as reinforcements is fabricates Al-6063 hybrid composites. The chemical arrangements of Al-6063 alloy is shows in Table 1. Cotton shells (CS) was collected from the cotoon crop feilds. and then after cleaning those shells with out cotton, nuts and dust. After compltely drining and then burn the shells with open atmospheric air at dry conditions. After burninig of cotton shells collected the refined ash then after sieve below 75µm. Then after the sieved shell ash is decorbonised at the temparature up to 500°c.It is ready for reinforcement for aluminium 6063. The temperature of the inside and outside furnace was precisely monitoring and perfectely controlled (±1ºC) usingmodrenthermocouples and PID controllers. The experimental framework of stir casting equipment used as 0.5 HP motor is revolves the stirrer with the blade at thenumerous speeds in bitween 100 to 2000 rpm; a hydraulic elevatorapparatus isutilize to guides the stirrer and help to moves up and down moments in contact with the composite material inside the furnace.

Constituent	AL	CU	CR	FE	MG	TI	SI	ZN	MN
Wt%	97.5	0.1	0.1	0.35	0.9	0.1	0.6	0.1	0.1

Table: 1 Chemical arrangements of Al-6063

In this approach the stir casting prosses is used for the fabrication of Al-6063 alloy with fraction of reinforcement of 0%, 1%, 2%, and3% of cotton shell ash (CSA) and silicon-carbide (Sic) particles of weight % on aluminium alloy 6063 is matrix material possess essential mechanical properties i.e high strength, fatigue, and ultimate tensile strength. It is used for following applications aircraft structure, automobile engines, defence applications.

Fig: 2 Preheated cotton shell ash (CSA)

Fig: 3 preheated SIC

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

Table:2 Chemical Compositions of SIC

2.2 Methodology For Stir Casting:

The bottom flow typeof fullymodernsensor based stir-Casting equipment is operated to fabricate the AL-MMHCs materials. Initially the matrix parent material AL-6063 alloy cut flakes dropped into the 2 kg capacity of furnace. The furnace temperature maintained around 800ºC centigrade. The matrix material AL-6063 is above 750ºC
temperature of material enhanceat most liquid stage. Then 10grams of c2cl6 is added for degasifing the molten melt. And maintains theorgan environment with the help ofpure organ gas. Earlier than stirring, the reinforcement is preheated 200◦*c* at 60 min. The stirring was done using by mechanical stirrer and the stirrer speed was maintained at 600 rpm and stirring time at 600 sec. And it's stirrer is dipped 2/3 of height of molten metal inside the furnace. During stirring operation both matrix material AL-6063 and reinforcements are mostly mixed. The die was preheated up to 450ºC at 1 hour. finally the moltenmelt aluminium hybrid composite was transferred into the metallic permanent die.

Fig: 4 Stir casting machine and die with twofinger composite piece

2.3 Processing Spacifications For Stir Casting:

PARAMETERS	UNITS	VALUES
Spindle rotations	Rpm	600
Stirring set-time	Seconds	480
Stirring temperature of the melts	ºC	750
Preheating temperatures of CSA-SIC	ºC	200
Preheating Time of The Reinforcements	Min	60
Preheating temperatures of die	ºC	450
Powder feed rate	g/s	1.2-1.3

Table: 3Process criteria for stir casting

2.4 Tests conducted:

1. Tribological Evaluation (wear behaviour)
2. Micro hardness
3. Density
4. Micro structure

3. Results and Discussion:

Description For Composite Fabricated:

Sample selections	% Wt (CSA: SIC)
0%	0
1%	75:25
2%	75:25
3%	75:25

Table: 4Samples Designation

CASTING	**AL 6063 gm (%)**	**Al 6063 (%)**	**REINFORCEMENT (Cotton Shell Ash + Silicon Carbide powder)**	**REINFORCEMENT (%)**
1	800	100	0	0
2	792	99	8	1
3	784	98	16	2
4	776	97	24	3

Table: 5 composition used for metal and reinforcement

3.1 TRIBOLOGICAL EVALUATION:

The term Tribology is defines the science and practices of interacting the surface in a relative motions. It also include the study and applications of principle of wear, friction and lubrications. Pin-on-disc tester is operate to assess the specific wear of composite materials during tesing of specimens gliding surfaces. These trailswasorganized under dry laboratory and standard non abrasive conditions according to ASTM standards. Schematic sketch of the pin-on-disc equipment is shown in Fig 5. The test trails were conduted by apply the basic loads of 10 N, 15 N, and 20 N and numorous sliding distances of 500, 750 and 1000m at several sliding velocities of 1 m/s, 1.5 m/s and 2 m/s respectively. The disc was made ofEN32 steel with a hardness of HRC 65. The AL-MMHC samples were fabricated aspinsof circular dimensions of 8 mm diameter with 30mm in height. The pins of glide on the disk at a track diameter of 60 mm,the lower surfaces of trail samples are plane and polished with metallographic alloy before testing. In order to maintains more clear-cut values of the wear rate of composie materials, each test trails was completedtwiceof the samples.

Fig:5 pin on disc tester

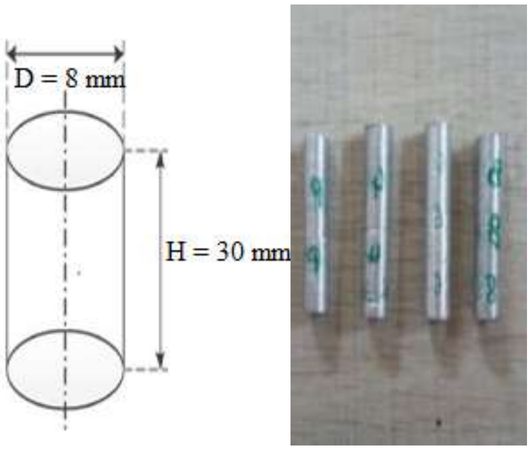

Fig: 6 specimens for wear test

Specifications for Wear Behaviour:

Track diameter =60 mm

Sliding velocity =1 m/s, 1.5 m/s,2 m/s

Speed =318 rpm, 478 rpm, 637 rpm

Reinforcement =0%, 4%, 6%, 8%

Sliding distances= 500, 750, 1000 m

Reinforcement %	Load (N)	Wear (micro meter)	Friction force (N)
0%	10N	68	3.3
	15N	77	5.0
	20N	98	7.3
1%	10N	66	3.6
	15N	67	5.8
	20N	73	7.1
	10N	60	3.3

2%	15N	61	5.7
	20N	63	7.6
3%	10N	59	4.0
	15N	84	6.1
	20N	87	6.9

Table: 6Wear behaviour and friction force at velocity= 1 m/s (318 RPM)

Reinforcement %	Load (N)	Wear (micro meter)	Friction force (N)
0%	10N	45	3.4
	15N	63	5.5
	20N	79	7.0
1%	10N	44	3.7
	15N	57	5.7
	20N	71	7.5
2%	10N	45	3.7
	15N	55	5.6
	20N	66	7.6
3%	10N	41	2.9
	15N	64	6.0
	20N	68	6.8

Table: 7Wear behaviour and friction force at velocity= 1.5 m/s (478 RPM)

Reinforcement %	Load (N)	Wear (micro meter)	Friction force (N)
0%	10N	42	3.8
	15N	48	6.7
	20N	51	7.0
1%	10N	36	3.7
	15N	42	5.7
	20N	48	7.5
2%	10N	34	3.3
	15N	32	5.0
	20N	39	6.6
3%	10N	47	4.0
	15N	69	5.8
	20N	100	8.1

Table: 8Wear behaviour and friction force at velocity= 2 m/s (637 RPM)

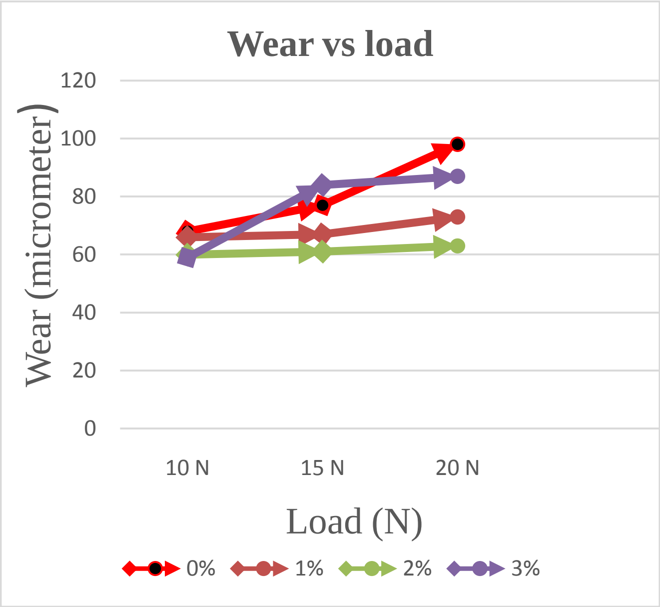

Fig: 7 Effect Of Wear Of Al 6063/ (CSA: SIC) Hybrid Composite At Velocity 1 m/s

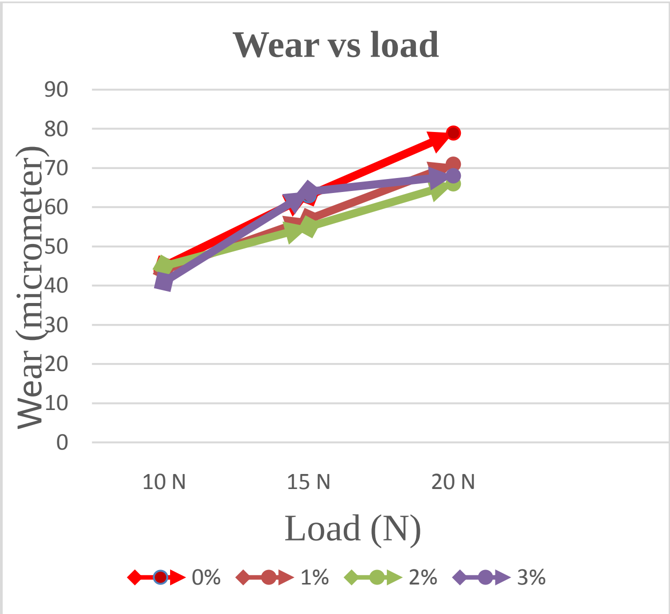

Fig: 8 Effect Of Wear Of Al 6063/ (CSA: SIC) Hybrid Composite At Velocity 1.5 m/s

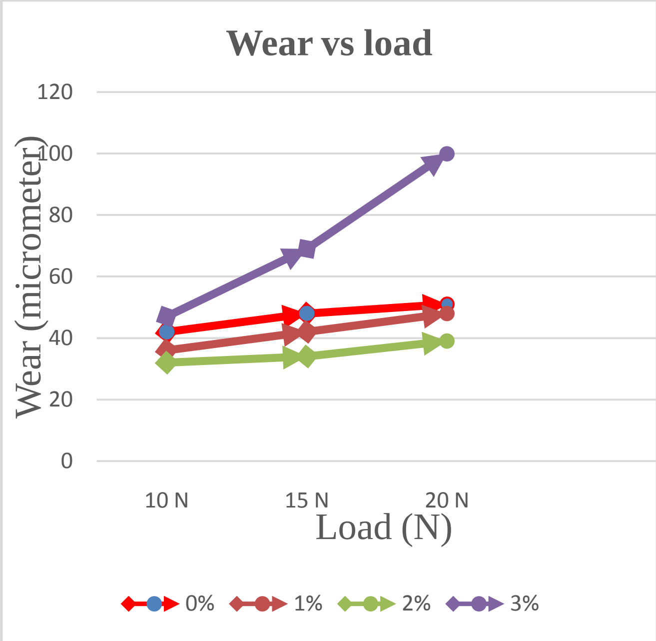

Fig:9 Effect Of Wear Of Al 6063/ (CSA: SIC) Hybrid Composite At Velocity 2 m/s

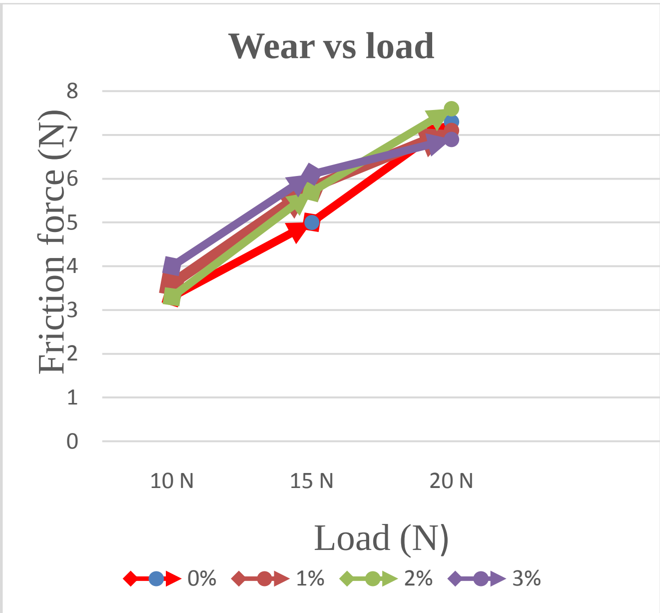

Fig: 10 Effect Of Friction Force Of Al 6063/ (CSA: SIC) Hybrid Composite At Velocity 1 m/s

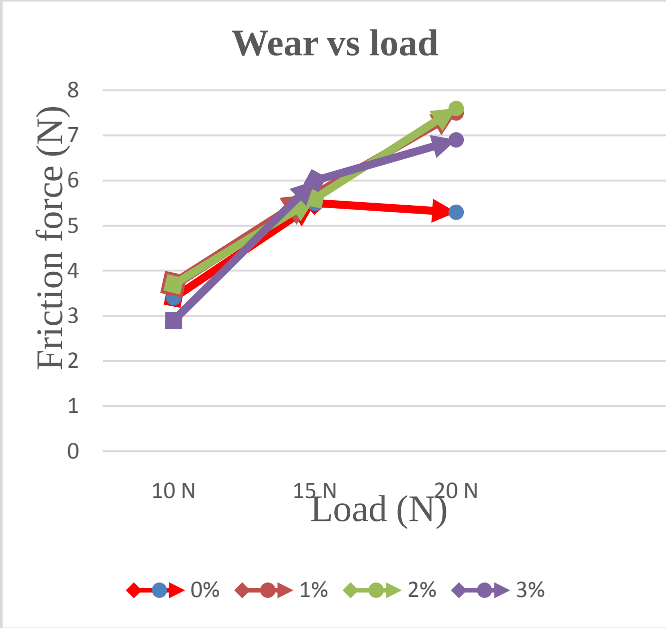

Fig: 11 Effect Of Friction Force of Al 6063/ (CSA: SIC) Hybrid Composite At Velocity 1.5 m/s

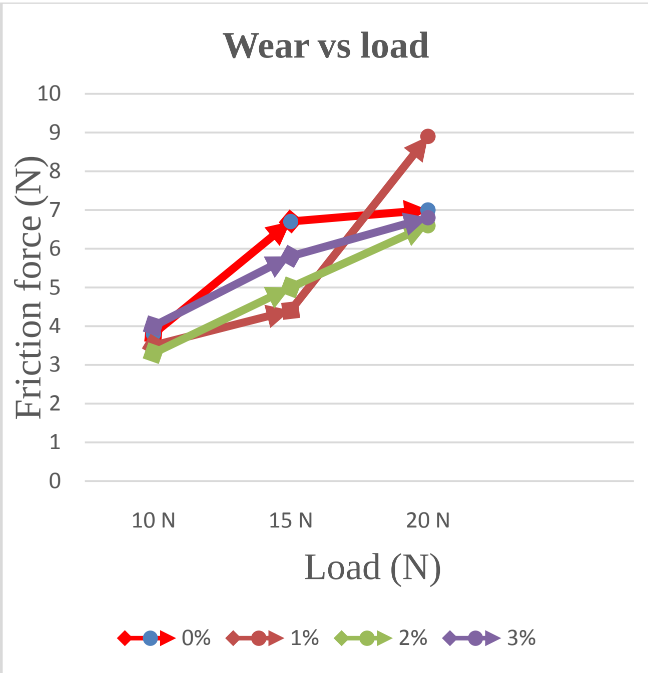

Fig: 12 Effect Of Friction Force of Al 6063/ (CSA: SIC) Hybrid Composite At Velocity 2 m/s

3.2MICRO HARDNESS:

Mechanical properties of al-6063 hybrid composite likemicro hardness of the fabricatedhybrid composites was evaluate byutilizing Vickers hardness tester with the scale of HRA. The samplesfabriation and testing proceedings for the micro hardness measuring was convey the followingof ASTM E-8 standards in those samples are suscetable to a straight load of 100 grams for 10s; multiple hardness trails wassupervised on each sample for precise results and the averages is taken as the microhardness of the fabriated AL-MMHC sample specimens.

Fig: 13 Vickers hardness tester

Reinforcement %	Hardness(BHP)			
	Trail 1	Trail 2	Trail 3	Average
0%	70.5	70.6	69.4	70.19
1%	78.1	71.5	69.4	73.07
2%	71.3	89.2	70.5	77.04
3%	84.8	82.2	76.4	81.14

Table: 9Micro Hardness of A-6063/ (CSA: SIC) hybrid composite

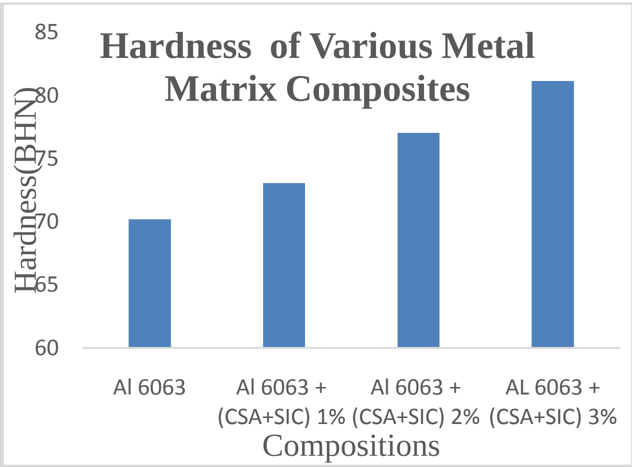

Fig: 14 Effect of Micro Hardness Al-6063/ (CSA: SICp) hybrid composite

3.3DENSITY:

The density of the AL-6063 Alloy Based Hybrid Metal Matrix Compositeevaluations was conveyedto the estimate the measurethe porosity of the fabricatedhybrid composites and in order to invistigate the infulence effect of the wt% portions of the cotton shell ash (CSA)-silicon carbide (SIC) of densities of the produced hybrid metal matrix composites.This was attained by differentiation ofthe experimental results to the theoretical resultsof the densities of each composition of hybrid composite specimensproportion weight %cotton shell ash

(CSA)-silicon carbide (SIC)reinforced hybrid metal matrix composites using standard procedures. The experimental density(EXT) wereevaluated by dividing the measured weight of hybrid metal matrix composite specimen by its measured volume. The theoretical density(T) was obtained by using method of rule of mixtures.

Fig:15 Density Tester

The % porosity was evaluated by using those relations:

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

S. No	SamplesDescription	Theoretical Density(g/cc)	Measured Density(g/cc)	%Porosity
1	Al 6063	2.72	2.69	1.10
2	Al 6063 + [CSA+SIC] (1%)	2.61	2.58	1.14
3	Al 6063 + [CSA+SIC] (2%)	2.59	2.555	1.35
4	Al 6063 + [CSA+SIC] (3%)	2.52	2.482	1.5

Table: 10 Density of Al-6063/ (CSA: SIC) hybridcomposite

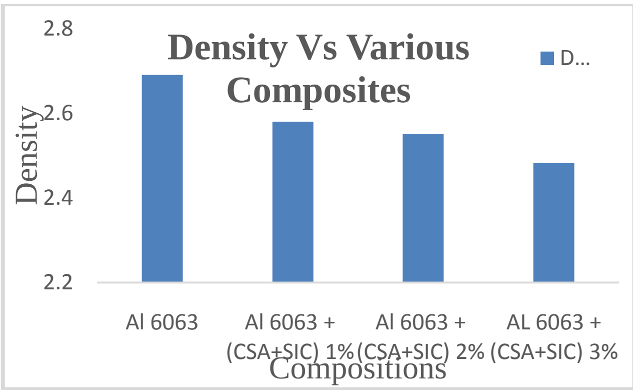

Fig: 16 Density of Al-6063/ (CSA: SIC) hybrid composite

3.4 MICRO STRUCTURE:

When a smoothly polished flat specimens reveals traces of its microstructure, it is normal to capture the images using microphotography. Most experienced microstructure evaluation involves costly high powered consumption instruments: optical microscope, X-rays diffraction, electron microscope. Some of the involving preparations of the composite material specimens (dimensioning, microtome, polishing, etching, vapor-deposition etc.). The methods are known collectively as metallographic as applied to metals and alloys, and composites.

There are two classifications in optical microscopes. Those are casually utilized to evaluate the flat-plane, smooth polished and etched specimens. A computerized inverted metallurgical microscope and ametallurgical Trinocularmicroscoperecording the image is achieved utilizing a digital camera working through the eyepieces.

A computerized inverted metallurgical Trinocularmicroscope with all accessories for analysing the microstructure images was captured utilized to evaluate the microstructure of the hybrid metal matrix composites. The micro structure of various hybrid metal matrix composites are as shown in fig.

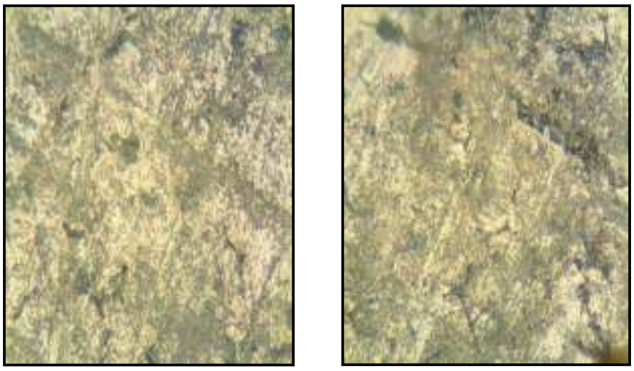

Fig: 17 Micro Structure of Al-6063

Fig: 18 Micro Structure of Al 6063 + [CSA+SIC] (1%)

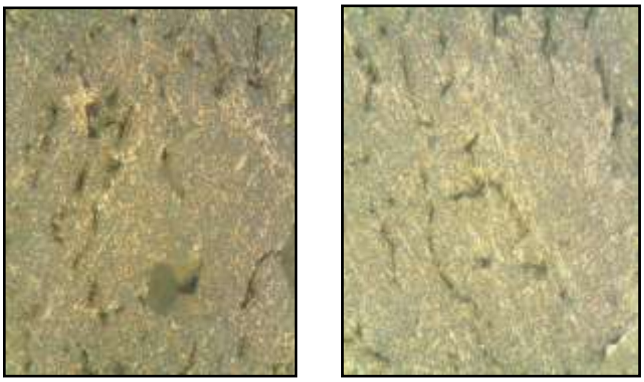

Fig: 19 Micro Structure Of Al 6063 + [CSA+SIC] (2%)

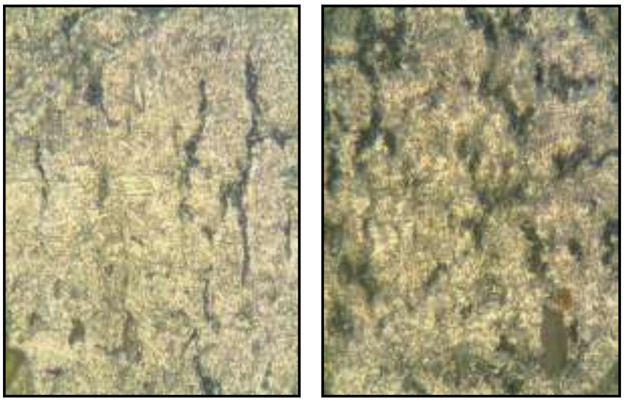

Fig: 20 Micro Structure of Al 6063 + [CSA+SIC] (3%)

4. Conclusions

Investigating the Influence of Cotton Shell Ash- SIC Weight Percentage on the Mechanical and Tribological Behaviour of Aluminium Alloy Based Hybrid Metal Matrix Composite containing with various proportions of 0%, 1%, 2%, and 3% are tested to find mechanical, metallurgical and tribologcialproperties such as Micro Hardness, density, wear behaviour, and micro structure of metal matrix composites.

We can conclude that by reinforcing with Cotton Shell Ash and silicon carbide. We have the following results:-

1. Cotton shells easily available from the naturally formed field crops. Exhibitinitiative potential as an attractive dispersoids to procure thelower-cost-high performance of AL-MMHCs.

2. Hybrid Metal matrix composite containing 75% of cotton shell ash (CSA)and 25% of silicon carbide (SIC) for 1 wt% and 2 wt% reinforcement showssuperior wear (tribologcial) behaviour.

3. The Vickers micro hardness of the AL-6063 alloy hybrid composite improves moderately with near the parent matrix base material AL-6063 alloy.

4. The density of the hybrid compositemoderately reduces for all 1 wt%, 2 wt% and 3wt% reinforcements as cotton shell ash (CSA)-silicon carbide (SIC)increases while there is significant changes in level of porosity.
5. Observations from microstructure:
   - Uniform mixing of 1% reinforcement (0.75% Cotton Shell Ash +0.25% Silicon Carbide).
   - Uniform mixing of 2% reinforcement (1.50% Cotton Shell Ash +0.50% Silicon Carbide).
   - Uniform mixing of 3% reinforcement (2.25% Cotton Shell Ash +0.75% Silicon Carbide).

Hence we can conclude that:

The optimum percentage of reinforcement in Al 6063 are 1% reinforcement such as 0.75% Cotton Shell Ash and 0.25% Silicon Carbide and 2% % reinforcement such as 1.50% Cotton Shell Ash and 0.50% Silicon Carbide are better mechanical, metallurgical properties and tribological Behaviour.

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