JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 3, 2022, p. 5394-5408
https://publishoa.com
ISSN: 1309-3452

Investigation of Mechanical and Wear Properties of Cu- Coconut Shell Ash Alloy Prepared by Powder Metallurgical Technique

M. Karthikeyan[1], K. Arul Raj[2], D. Narmatha[3],

[1]Professor, Department of Robotics and Automation, Raja Rajeswari College of Engineering, Bengaluru.

[2]Professor, Department of Mechanical Engineering, Einstein College of Engineering, Tamilnadu.

[3]Assistant Professor, Department of Electronics and Communication Engineering, Einstein College of Engineering, Tamilnadu.

Received: 2022 March 15; **Revised:** 2022 April 20; **Accepted:** 2022 May 10

Abstract

In this research, experimentations were made on wear characteristics of fabricated copper composite and also evaluated its mechanical properties. Currently the researchers shows the interest in manufacturing the engineering products from the waste material because of its abundant availability and cheaper. In this research coconut ash was produced from coconut shell used as a reinforcement. The copper metal matrix composite is fabricated with copper-90%, lead-3%, tin-1%, zinc stearate-1% and coconut shell ash-4%. The alloy with lead and tin strengthens copper and also increases the wear properties.The coconut shell ash also contributes in improving the wear resistance.At room temperature, the wear test were carried out at a purpose built pin on apparatus. The composite were tested at 390MPa compact pressure and at 600^{o}C sintering temperature. The results show that the wear behaviour change and the copper composite reduces the wear rate and increase the material life time.The mode of wear was characterised by using Scanning Electron Microscope.

Keywords: Wear, Load, Sliding velocity, Sliding distance, wear resistance, friction coefficient

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INTRODUCTION

Metal matrix composite is manufactured by the powder metallurgical techniques to produce the composites with high density variation. The matrix and reinforcement combined composite provides the properties greater than the individual properties of the components. In Industries, copper alloys are mostly used due to the good thermal and electrical conductivity properties. It also has the properties of high corrosive resistance and stability at elevated temperature. Coconut shell ash is used as a reinforcement to strengthen the metal matrix. It contains silicon oxide, aluminium oxide, iron oxide and magnesium oxide. Due to the presence of these oxides, it acts as good filler.

The aluminium metal matrix with the coconut ash samples reported that increase in wear resistance and adding coconut shell ash reduces the toughness of the composite [1]. Studies found that the performance of an alloy with the improvement of strength and stiffness property is due to the addition of reinforcement [2]. Experimentation on copper with fly ash composite shows that the impact of compaction pressure, sintering temperature on wear behaviour increases the density, hardness and wearsresistance [3]. The observation on copper composite with the fly ash resulted that decrease in yield strength and increased wear resistance with the addition fly ash [4]. Material surface hardness increased due to the formation of solid –state bonding by diffusion with the increase of sintering temperature [5]. Higher densification gives rise to material hardness whereas higher compaction pressure decreases the porosity of the composite and provides higher densification [6, 7].

The material made of aluminium and coconut shell ash provides higher friction coefficient. On adding the coconut shell ash to the aluminium alloy can able to withstand higher forces and this material lasts longer [8]. Study on aluminium alloy reinforced with coconut shell ash shows that the coconut ash decreases the composite density and increase the porosity and hardness of the aluminium composite material [9]. Researchers found that carbon shell ash has the highest activated carbon which has its applications in reinforcement, filler, coarse aggregate and energy source due to its durability and high adsorption capability [10].Datau et al explore the potentials of coconut shell ash and kyaniteparticles used for the preparation of aluminium metal composite. It results that the presence of crystalline phases in coconut shell ash and kyanite particles provides good strength and wear characteristics [11].

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Experimentation of copper fly ash composite results that increase in reinforcement addition increases the wear rate for all sliding velocities. The change in wear behaviour observed was plastic deformation. At higher loads, delamination occurs and at lower loads grooves occurred due to ploughing [12-14].Research on reinforcement for the copper matrix composite to improve the strength and wear resistance with compact cost and weight.It is found that the addition of hard reinforcement with the copper matrix such as oxides of aluminium and silicon, carbides of silicon and titanium shows better wear resistance [15-19].Sarki et al investigated the coconut shell particulates to be used as fillers in the eco-composite material. The investigation results that coconut shell has higher tensile strength, hardness and modulus of elasticity [20].

In this project, the experimentation is on analysing the mechanical and wear properties of copper composites made with 5wt. % and 10 wt. % reinforcements of coconut shell ash. The sintered density, porosity, hardness and wear rate of the composites are studied.

MATERIANLS AND METHODS

Materials Composition

The copper –coconut shell ash metal matrix composite can be formed by using 90% of copper as matrix and 3% of lead and 2% of tin and 1% zinc stearate and the reinforcement of 4%coconut shell ash.

Coconut Shell Ash Preparation

In daily life, coconut has many uses as food, oil, drinks, charcoal, cosmetics and decorations. The coconut shells are produced in huge quantity as agricultural solid waste. It was collected from coconut drink vendor, temples and farms. It was manually broken and made it sun-dried for couple of days. The dried coconut shells were crushed into tiny particles and then sieved to fine powder. Coconut shell ash was prepared by heating the powder placed in electric furnace at 850^{o}C for four hours. The ash powder was sieved to size of 53µm using a 300 mesh screen. The coconut shell ash powder chemical composition was shown in Table 1.

Table 1 Coconut shell ash powder chemical composition

Element	Al_2O_3	ZnO	CaO	SiO_2	MgO	MnO	Na_2O	K_2O	Fe_2O_3
%	15.78	0.32	0.58	45.12	16.3	0.24	0.47	0.54	12.3

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Specimen Preparation

Metal matric composites were made with copper and 5wt% of coconut shell ash as one composite and another by varying the weight % of reinforcement to 10%. The die in which the specimen was to be compacted was initially lubricated by using graphite powder for easy and smooth ejection. It was applied to the contact surfaces, fasteners and plungers of the die. The Copper, lead, zinc stearate, tin powders and coconut shell ash were mixed well to make the metal matrix composite at perfect shape. The powder mixed was filled into the die with compaction after each small quantity of powder used.

The powder filled die was fixed to the plunger top and the entire setup was fixed on the UTM as shown in Figure 1(a,b). According to the die strength, varied pressure was applied .In order to protect the specimen from damage, the pressure should be applied evenly and slowly. When the required pressure was attained, the UTM was stopped and then specimen to be ejected.

Figure 1a. Plunger

Figure 1 b. Die fixed on base

For specimen ejecting, first the die was removed from base and kept at certain height. As like previous the pressure was applied to the specimen. Since there was no base the specimen was ejected through the bottom.Then the ejected specimen was sintered in a furnace at a controlled temperature of 600^{o}C for at least three hours. After switching off the furnace, the specimen was allowed to cooling to make ready for wear testing.

COMPOSITE TESTING

Density & Porosity

The copper composite density was determined by the Archimedes principle by the following equation.

$$Density\ of\ the\ copper\ Composite = \frac{W}{W - W_1} X density\ of\ distilled\ water$$

Where W & W_1 is the weight of the composite in air and in distilled water respectively. Theoretical density value of the copper composite by the following equation

$$Density = reinforcement\ weight\ ratio\ X\ reinforcement\ density + (1 - unreinforced\ copper\ alloy)$$

The average calculated & measured density values of the test specimens were specified in the Table 2.

Table 2. Density Variations of Composites

Test Specimen	Density (g/cm^3)	
	Theoretical	Practical
Copper Alloy	8.94	8.94
Copper Alloy - 5% Coconut ash Composite	8.80	8.75
Copper Alloy - 10% Coconut ash Composite	8.53	8.47

The porosity of the specimen was calculated using the following equation

$$Porosity = 1 - \frac{Measured\ Density}{Calculated\ Density} X100$$

The copper alloy and its composite's porosity were tabulated in the Table 3.

Table 3. Porosity Variations of Composites

Test Specimen	Porosity
Copper Alloy	0%
Copper Alloy - 5% Coconut ash Composite	0.57%

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Copper Alloy - 10% Coconut ash Composite	0.71%

Hardness

The hardness of the copper-coconut shell ash composite is measured by Vickers hardness tester. The material hardness indicates the deformation of plastic resisting capability of the copper alloy hardness and reinforcement hardness. Table 4 represents the estimated values of the hardness test for the test specimens.

Table 4. Hardness Variations of Composites

Test Specimen	Hardness
Copper Alloy	138
Copper Alloy - 5% Coconut ash Composite	151
Copper Alloy - 10% Coconut ash Composite	172

Wear Test

The specimen is sintered and subject to wear testing which is on the pin on disc experiment. The specification of the pin and disc is tabulated in the Table 5. The Pin on disc apparatus is shown in the Figure 2.

Table 5 Specification of Pin & Disc

Specification	Pin	Disc
Diameter	8mm	300mm
Height / Thickness	15mm	15mm

Figure 2 Pin on Disc Apparatus

The initial height and weight of the specimen are measured to find the wear rate. For this experimentation, the abrasive grit papers of different grades as 1/0, 2/0, 3/0 and 4/0 is used as shown in Figure 3. The emery sheets are pasted on to the disc of the pin on disc apparatus. The specimen is made to hold on to the pin of the pin on disc apparatus using

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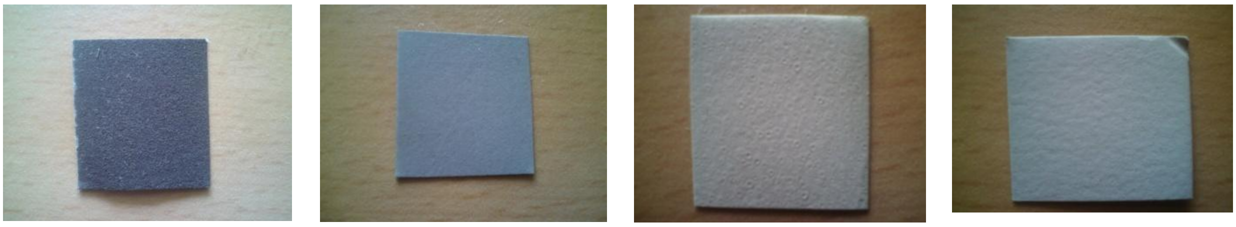
holder. The pin with specimen and the disc with abrasive paper are now brought to contact.Now the motor is switched so that the disc will rotate and wear will occur to the specimen. The speed of the motor can be varied using variac. Different parameters are changed to find the wear at different conditions. The parameters that are varied are applied load on the specimen, grades of emery sheets, speed of the motor, and the compacting pressure on the specimen.

Figure 3. Various grades of Abrasive Grit



1/0 2/0 3/0 4/0

The experiment is carried out for 60sec for each variable. After the experiment the final weight and height of the specimen is measured. Using the formulas different parameters like weight loss, specific wear rate, and sliding velocity are found. The Pins Compacted at 390MPa is shown in Figure 4. The values are tabulated as in Table 6.

Figure 4. Pins Compacted at 390 MPa

Table 6 Effect of load in wear rate tested using varied grit size and speed

Specimen	Grit Size : 4/0				Grit Size : 2/0		
	Speed	300 rpm	400 rpm	500 rpm	300 rpm	400 rpm	500 rpm

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	Load	Wear rate	Wear rate	Wear rate	Wear rate	Wear rate	Wear rate
Copper	50	0.07	0.09	0.14	0.28	0.34	0.37
	70	0.11	0.17	0.18	0.36	0.51	0.67
	90	0.15	0.32	0.33	0.4	0.7	1.04
Copper -5% composite	50	0.02	0.03	0.07	0.07	0.12	0.13
	70	0.03	0.05	0.07	0.12	0.13	0.16
	90	0.06	0.07	0.09	0.15	0.17	0.2
Copper -10% composite	50	0.02	0.02	0.04	0.05	0.06	0.08
	70	0.02	0.03	0.04	0.06	0.08	0.12
	90	0.05	0.04	0.06	0.09	0.09	0.13

RESULTS & DISCUSSION

The composite prepared using copper alloy as metal matrix and the reinforcement is chosen as coconut shell ash which provides enough tensile strength. The copper alloy has lead, tin and zinc stearate composition. The results of the process parameters includes density, porosity, hardness and wear rate are discussed below.

Density, Porosity, Hardness Studies

The prepared composite density are measured on the basis of Archimedes principle. Figure 5 illustrates the density variations of copper alloy and the copper-coconut shell ash composite with 5% and 10% reinforcement. Here the inner circle values indicates the theoretical density values and the outer circle represents the measured density value for copper and its composites. It is inferred that the measured density value is lower than the theoretical value due to the presence of coconut shell ash content in the copper-coconut shell ash composite. And also the density value decreases with the increasing the addition of coconut shell ash to the copper matrix.

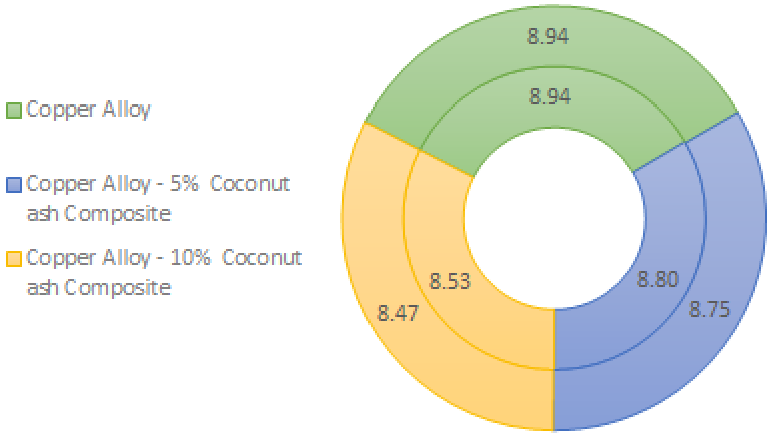

Figure 5 Density Variations of Composites

The porosity variations of the copper alloy and its composites is shown in the Figure 6The porosity values depends on the measured and calculated density values of the composites. The porosity value increases with increasing the addition of reinforcement.

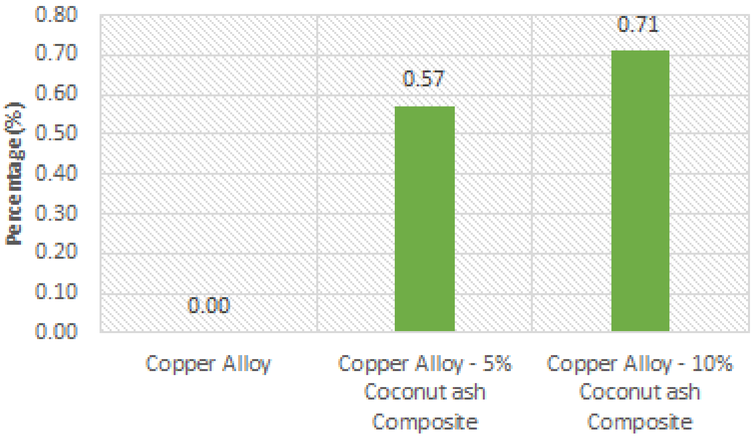

Figure 6 Porosity Variations of Composites

The hardness variations of the copper alloy and its composites is shown in Figure 6. The hardness test values are obtained by the Vickers hardness tester. The test results shows that the value increases from 138 VHN for copper alloy to 175VHN for the composite with 10wt% reinforcement. The hardness of the composites raises as the coconut shell ash percentage in the composite increases.

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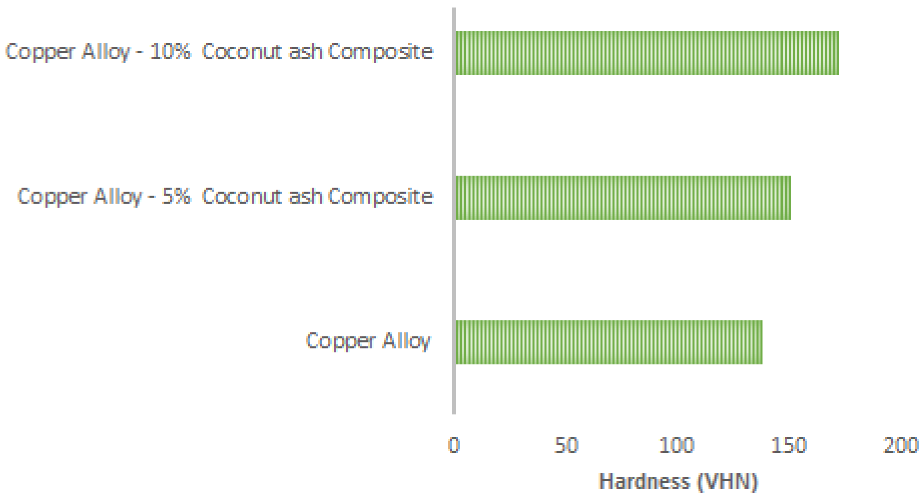

Figure 7. Hardness Variations of Composites

Wear Test

The results of Tribo-graphs lead to friction and wear data, generally referred to as tribo-data, which are system dependent characteristics presented in form of Tribo-graphs. Tribo-graphs are graphical representation of a measured friction of a measured friction or wear quantity as a function of operational parameters (load, speed, abrasive grit size, compacting pressure), structural grit size (material pairing, hardness and roughness) and interaction parameters (contact stresses, film thickness to roughness ratio). Here the graphical representation of the tribo-data is based on operational parameters.

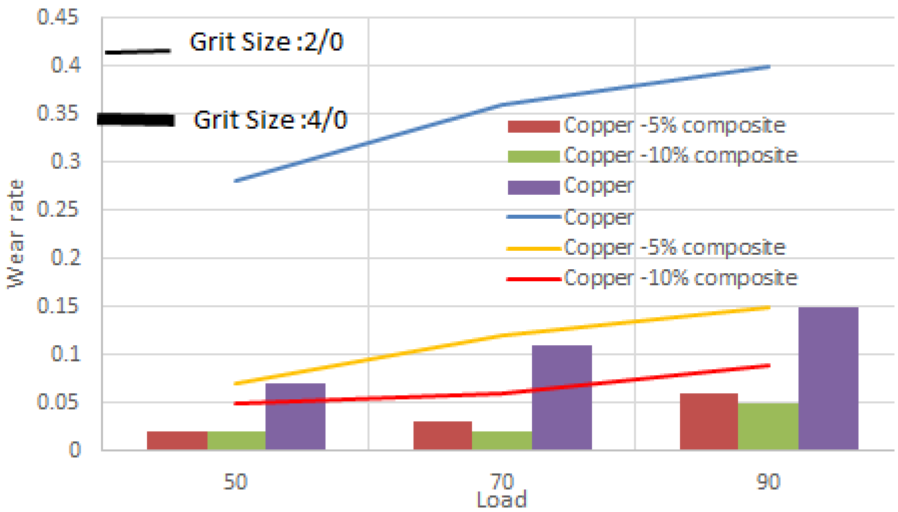

Figure 8. Effect of load in wear test when tested at speed of 300 rpm

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Figure 8 shows the graph between the wear rate and the applied load at room temperature and compacting pressure as 390 MPa. To obtain the deviation different abrasive grit papers are used. The results indicates that increasing the load increases the wear rate. The results are measured at the speed of 300rpm and the grit size 2/0 and 4/0. In the graph the line indicates the grit size 2/0 and the bar indicates the grit size 4/0. It also displays that the wear rate is reduced in the copper –coconut shell ash composite compared to the copper alloy.

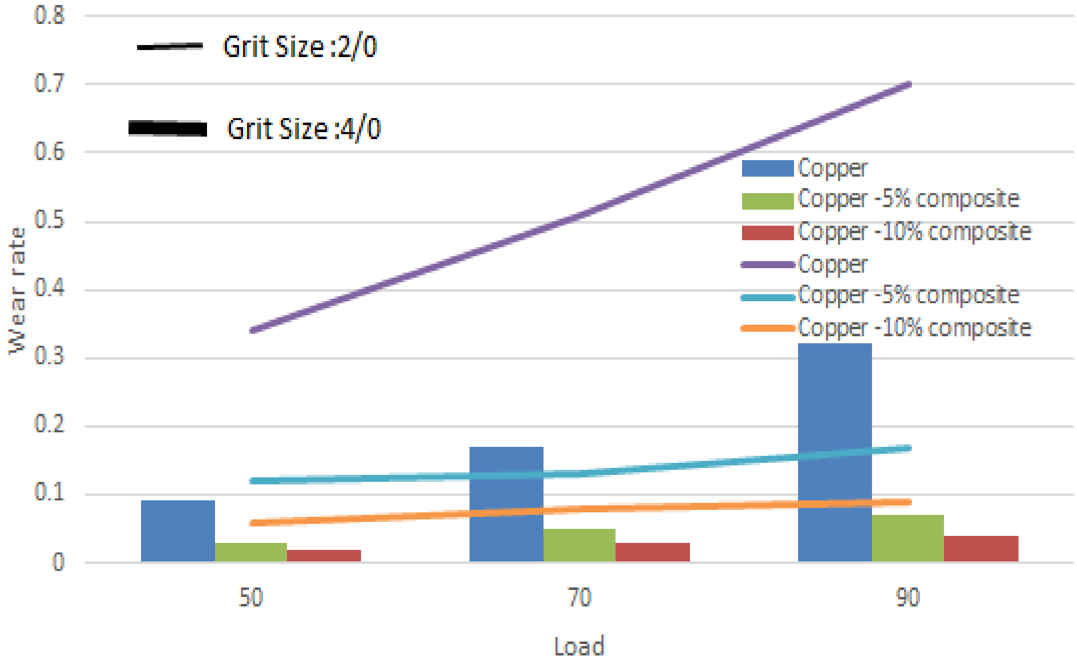

Figure 8. Effect of load in wear test when tested at speed of 400 rpm

Figure 9 shows the graph between the wear rate and the applied load at room temperature and compacting pressure as 390 MPa. To obtain the deviation different abrasive grit papers are used. The results indicates that increasing the load increases the wear rate. The results are measured at the speed of 400rpm and the grit size 2/0 and 4/0. In the graph the line indicates the grit size 2/0 and the bar indicates the grit size 4/0. It also displays that the wear rate is reduced in the copper –coconut shell ash composite compared to the copper alloy.

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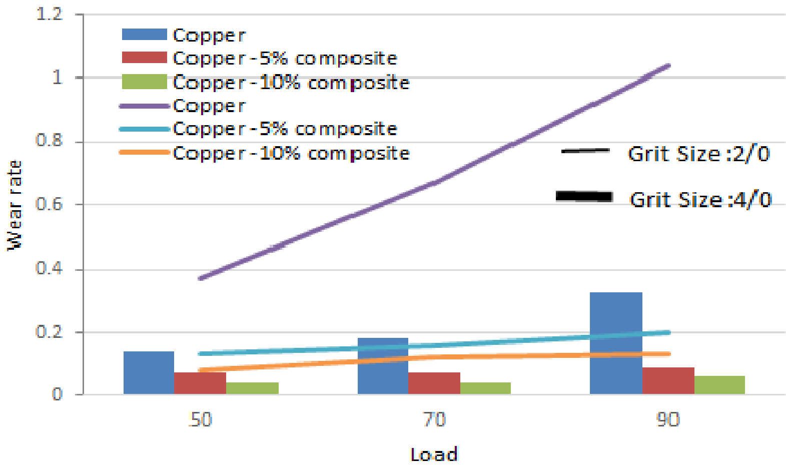

Figure 9. Effect of load in wear test when tested at speed of 500 rpm

Figure 9 shows the graph between the wear rate and the applied load at room temperature and compacting pressure as 390 MPa. To obtain the deviation different abrasive grit papers are used. The results indicates that increasing the load increases the wear rate. The results are measured at the speed of 500rpm and the grit size 2/0 and 4/0. In the graph the line indicates the grit size 2/0 and the bar indicates the grit size 4/0. It also displays that the wear rate is reduced in the copper –coconut shell ash composite compared to the copper alloy.

The microstructures of the copper- coconut shell ash composite is determined through SEM are presented in the Figure 10. It shows the microscopic images of the copper- coconut ash composite compacted at 390MPa sintered at 600^{o}C about half an hour.

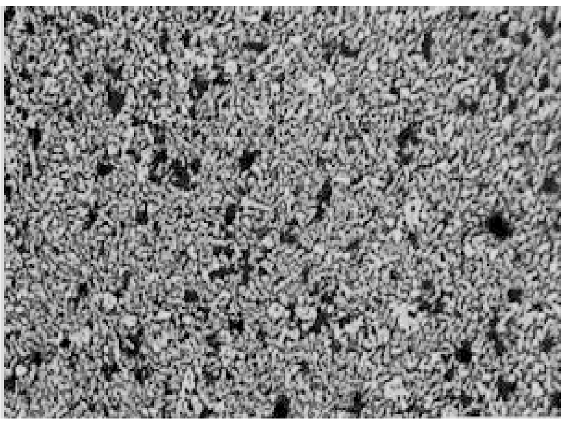

Figure 10. Microstructure of the composite processed under 350MPa

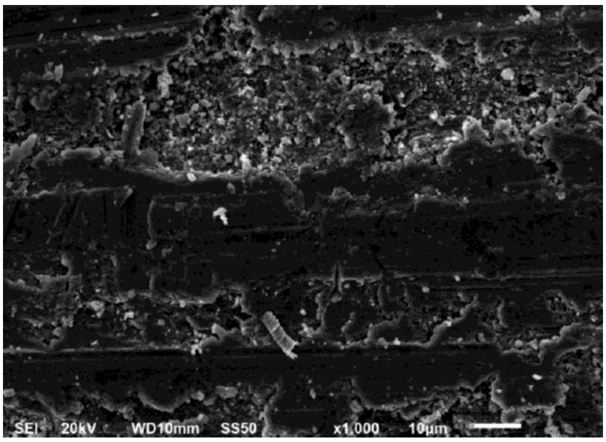

Figure 11 Wear surface Delamination

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Figure 11 displays the delamination of the wear of the copper-coconut shell. It is due to the presence of cracks in the composition. The particles for the wear test are dragged out from the matrix and made contact with the pores which in turn increases the risk of crack formation at the pores in the contact region.

CONCLUSION

The experiment includes the composite fabrication and estimation of the parameters such as density, porosity, hardness and wear characteristics. The conclusion can be made from the investigation of copper-coconut shell ash composite fabricated via the powder metallurgy and the evaluation of its properties as follows,

- The coconut ash powder decreases the density of the composite. By increasing the percentage of the coconut shell ash particulates to the composite inferred that it further decreases the composite density. The practically obtained densities were lower than the theoretical value which may due to the increasing coconut shell ash content.
- The coconut ash powder increases the porosity of the composite. By increasing the coconut ash particulates percentage to the composite inferred that it further increases the composite porosity.
- The composite of Cu-coconut ash hardness is higher when compared to copper alloy hardness.
- Copper alloy is replaced by its composite reduces the wear rate and increase the material life time
- The wear resistance increases due to the van der wall force.

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