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Investigation of the Impact of Silicon oxide Nano Particles in the Copper Satellite Composite

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ABSTRACT

The main objective of this paper is to study the effect of the Silicon oxide nano particles in the copper Compositewhich is manufactured by using the stir casting process and samples are prepared as per the ASTM standards. These specimens are tested under the mechanical tests. Due to blending of the nanoparticles the properties of copper Compositewill be enhanced. so uniform ASTM samples with varying composition of nano particles are manufactured and compared with the copper Compositewithout reinforced particles. Its main application is found in journal bearings, rotary rock bits in oil and gas industry and they can also bear mechanical and thermal shocks. The scratch and wear properties are enhanced by adding silicon oxide nano particles so these properties are tested by conducting wear test& scratch test for scratch hardness.

1 INTRODUCTION

Copper Alloys have wide application in naval, marine, oil and gas industries. Naval brass is one of such copper Composite having chemical composition as shown in Table 1. Cu Alloys is mixture of Cr, C, W, Fe and Ni and they are used for high temperature wear resistance, corrosion resistance. Copper Compositeis manufactured by stir-casting process. The mechanical properties of copper Compositecan be altered by adding silicon oxide nano particles. To test the effect of these silicon oxide nano particles, copper Compositewith various compositions of nano particles are made. The scratch and wear tests can be performed to observe the improved properties.

A novel Tin/Bronze alloymaterial coated on planet journal gave reduced friction coefficient and better wear resistance [1]. Stellite deposited on plain carbon steels using TIG cladding have shown corrosion, wear and oxidation resistance. The carbides present in Co-Cr Composite has this special properties [2]. A new series of stellite “Co-Cr-M-C” has better wear and corrosion resistance in reducing environment. The scratch test conducted on this new stellite has shown better cracking resistance property [3]. Centrifugally cast Copper Composite with graphite composites (C90300/ 10%graphite) has shown improved wear resistance when compared with leaded copper Composite(18-22% Pb). The friction coefficients remain same for the two types of materials [4].

Copper based alloymaterials made with carbon fibre reinforcements have high wear resistance, high heat conductivity and commonly used in electronic products. Production cost of alloymaterials is high. Cast method and powder metallurgy methods are two commonly used methods for production of alloymaterials [5]. Al-Cu based metal matrix composites reinforced with SiC particulates made by disintegrated melt deposition technique have shown good interfacial integrity when compared with conventional casting methods. Micro structural homogeneity and low porous volume are observed in the disintegrated melt deposited alloymaterials [6]. Cu-Sn10N5/Si_3N_4 composites have shown increased micro hardness values and tensile strength when compared with unreinforced Alloy. Grain boundary strengthening, particle-strengthening and dispersion strengthening are observed in the Si_3N_4 reinforced alloymaterials [7]. Friction coefficient and wear studies done on Cu matrix reinforced with SiC nano particles and carbon nano tubes revealed that the wear has decreased and lower friction coefficient values are observed. Oscillation was observed low when compared with other alloymaterials having two or more reinforced particulates [8]. Cu-10Sn Composite and its composites made by reinforcing SiC within varying wt% have exhibited increased micro hardness. The wear rate was observed to be increased with increased distance and load. The wear was observed to be decreased in the beginning and latter increasing with increase in velocity [9]. Microindentation and nanoindentation done at various positions revealed increased hardness

Table 1: Specimen composition:

element	Chromium	Tungsten	Carbon	Iron	Nickel	SiO_2	Copper
content	5	11-13	0.5	1	1	1,1.5,2,2.5,3	remaining

value in case of Cu based SiC and multi walled CNT hybrid composites. With multiple reinforcements the hardness value of the alloymaterial was experimentally found to be increased. With increased CNT wt% the electrical conductivity is reduced [10]. Better corrosion rate and reduced wear rate is reported by R. Venkatesh et al. [11] while studying the tribological properties of Cu based alumina and graphite reinforced hybrid metal matrix composites. They reported better wear rate with nano level reinforcement and increased proportion of graphite.
SiC and graphite reinforced copper based metal matrix composite's metallographic properties are studied by C. S. Ramesh et al. [12]. The softer graphite reinforcement material is used to reduce friction coefficient and obtain optimum properties.
They hinted increased Microhardness and tensile strength values. Also they observed improved tribological properties with coated reinforcements.
Ibrahim C et al. [13] investigated the effect of particle fraction on density, dry sliding wear resistance and electrical conductivity of Ni_3Al particle reinforced Cu based metal matrix compos ites. Density and electrical conductivity is observed to be decreasing with increased reinforcement. Compression yield strength is observed to be less when compared with unreinforced metal and wear resistance is reported to be increased with increased particle reinforcement. Effect of nanometre diamond reinforcement in Cu10Sn Composite is studied by Yingwei Xiang et al. [14]. The reinforced alloywas found to have high hardness and low bend strength.
Friction coefficient is decreased due to the presence of nanometre diamond in the quasi-spherical debris.

1.1 Scope of the work

In the above literature it is observed that carbon nano tubes, nanometre diamond has increased the hardness and reduced friction coefficient.C46400 copper Composite has wide applications in bearings, corrosion resistance requirements, nut and bolts, precision shipboard equipments. Not much study is done on the effect of reinforcement of SiO_2 nano particles in the Cu composite . The scope of work for the current study is to prepare SiO_2 reinforced Cu Composite matrix by doing ball milling and stir casting for studying wear and elastic modulus of the material.

- To prepare samples for scratch test and wear test
- To study the elastic modulus and wear rate of the Cu46400/SiO_2 metal matrix composite

Bruker's UMT Tribolab scratch tester is used to perform scratch test. Variation of coefficient of friction is studied along the scratch path and elastic modulus values are obtained. Wear test is conducted on pin on disc tribometer to obtain wear rate of the material..

Keywords: SiO_2 nano powder, wear test, scratch test, ball milling, stir casting, linear elastic module.

2. MATERIALS AND SPECIMEN PREPARATION

Copper Composite is taken as base matrix. SiO_2 is considered as reinforcing material. SiO_2 nano powder, W, Cr, C, Si, Fe and Ni are ball milled to get powdered Composite material. First all the elements except copper are taken according to their weight percent and ball milled. SiO_2 weight percent is varied as
1, 1.5, 2, 2.5%. Then Cu chips and ball milled powder with varying wt% of SiO_2 are stir casted. One specimen is prepared without any SiO_2 content.

Specimens are made into 12 mm diameter and 40 mm length cylinders for conducting wear test. 55mm X 55 mm X 10 mm square plates are made to perform scratch test.

3. EXPERIMENTATION

Scratch test is conducted on the samples taking starting load 20N, finishing load 20N, stroke length 10mm and scratch velocity as 0.1 mm/sec as specified in Table 3. Experiments are done with all five samples. The Wear test is performed on the pin on disc wear testing machine with the five samples. The rotational speed of disc is taken as 400 rpm, load 3kg and time 9.36 minutes. In all experiments wear rate is noted down.
Wear rate is considered as the volume removed per unit distance. It's units are m^3/m. Wear test was conducted on all samples by using the test conditions

as specified in Table 2. Both wear test and scratch test are done according to ASTM standards.

4. RESULTS AND DISCUSSION

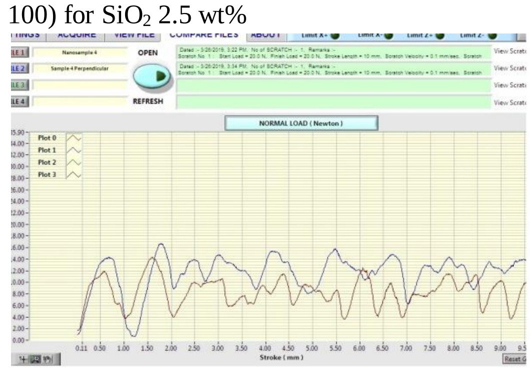
ScratchScratch test results obtained are plot as traction force/ frictional coefficient against stroke. The plots are obtained for all specimens (Fig. 1, Fig. 2, Fig. 3 and Fig. 4)and comparison plots (Fig. 5) are drawn to compare the traction force / frictional coefficient values in different cases. Traction force / Coefficient of friction value in case of no SiO_2 was observed to be less when compared with SiO_2 reinforced alloy. The traction force / coefficient of friction value is increased with increased wt% of SiO_2. This confers increase in scratch hardness from 0.39 GPa to 0.56 GPa with reinforcement of SiO_2 nano particles. With increment of SiO_2 wt % the scratch hardness value increased. This is due to abrasive nature of SiO_2 nanoparticles present in the metal matrix composite. The force required to make a scratch on the alloyis increased because of the presence of SiO_2 nanoparticles. The comparison plot drawn between scratch test results with no SiO_2 wt% and SiO_2 2.5 wt% reported the decrement of traction force with reinforcement of SiO_2.

The wear test conducted on five samples has shown that with reinforcement of SiO_2 the wear rate is reduced to 1.17 X 10^{-7} m^3/m when compared with no SiO_2 component which is equal to 1.82 X 10^{-7} m^3/m. With increase in SiO_2 wt% the wear rate is reduced. With SiO_2 wt% being 1 the wear rate obtained is 1.783 X 10^{-7} m^3/m and with SiO_2 wt % being 2.5 the wear rate obtained is 1.110 X 10^{-7} m^3/m. Presence of blended abrasive SiO_2 nano particles improved the resistance to wear. With increment of SiO_2 wt% abrasive nature increase further and wear decreases.

Fig. 1 Normal load & traction force (N)/ Coefficient of friction (x100) for SiO_2 1 wt%)

Fig. 3 Normal load & traction force (N)/ coefficient of friction (x 100) for SiO_2 2 wt%

Fig. 4 Normal load & traction force (N)/ coefficient of friction (x 100) for SiO_2 2.5 wt%



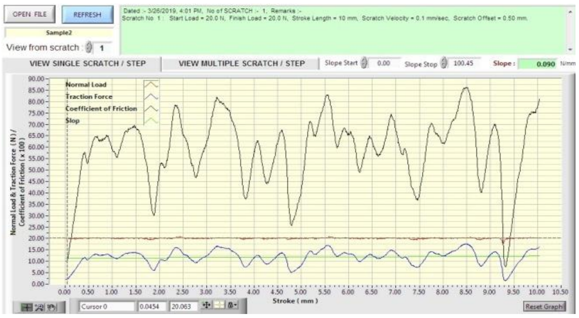


Fig. 2 Normal load & traction force (N)/ Coefficient of friction (x100) for SiO_2 1.5 wt%)

Fig. 5 Comparison of Normal load & traction force (N)/ coefficient of friction (x 100) for SiO_2 2.5 wt% and no SiO_2

Wear rate can be calculated by wear volume divided by

W = V/d

W = wear rate

V= wear volume

d = sliding distance

sample calculation:

W = 1.141e-4/999.54 = 1.142e-7 m^3/m

Specimen no	rpm	Track Dia	Load	Track length	time	Wear rate
1(1%)	400	85	3kg	1000m	9.36 min	1.783×10^{-7} m^3/m
2(1.5%)	400	85	3kg	1000m	9.36 min	1.607×10^{-7} m^3/m
3(2%)	400	85	3kg	1000m	9.36 min	1.142×10^{-7} m^3/m
4(2.5%)	400	85	3kg	1000m	9.36 min	1.110×10^{-7} m^3/m
5(No SiO_2)	400	85	3kg	1000m	9.36 min	1.180×10^{-7} m^3/m

Wear rate:

for sample 3 having 2 wt % of dispersed SiO_2

W = V/d

V = pin dia X wear depth

= 3.14 X 0.2 X 0.2 / 4 X 0.0036

= 1.141 e-4 m^3

d = linear sliding velocity X test time

d = track radius X angular velocity of disc X test time

d = 0.085/2 X 2 X 3.14 X 400 / 60 X 9.36 X 60

d = 999.54 m

scratch hardness:

$HS_p = 8P/\pi w^2$

P is normal load, w is average scratch width [15]

For sample 3, P = 20 N, w= 312 µm

HS_p = 8 X 20/(3.14 X $(312\ e\text{-}6)^2$)

= 0.52 GPa.

For sample 4, P = 20 N, w= 301 µm

HS_p = 8 X 20 / (3.14 X $(301e\text{-}6)^2$)

= 0.56 GPa.

Table 2. Wear rate of samples with 1, 1.5, 2, 2.5 and no SiO_2 wt %

Table 3. Scratch hardness of samples with 1, 1.5, 2, 2.5 and no SiO_2 wt %

Specimen no	Normal load- Kg	Average scratch width- µm	Scratch hardness- GPa
1(1%)	20	348	0.42
2(1.5%)	20	329	0.47
3(2%)	20	312	0.52
4(2.5%)	20	301	0.56
5(No SiO_2)	20	361	0.39

5. CONCLUSIONS

1. Samples are prepared with varying wt% of SiO_2 nano powder to compare the effect of SiO_2 reinforcement in Cu Composite matrix.
2. It is observed that the wear rate is reduced with SiO_2 reinforced Cu Composite alloymaterial from 1.180 x 10^{-7} m^3 / m to 1.110 x 10^{-7} m^3 / m .
3.. The scratch hardness which is a function of normal load and average scratch width is increased from 0,39GPa to0.56 GPa with reinforcement of SiO_2 in Cu Composite base matrix.

4. The tribological properties of Cu Composite are improved with SiO_2 reinforcement.

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