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Study of Mechanical and Tribological Behaviour of Cu-SiCp Metal Matrix Composites

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Abstract: ***Copper Silicon carbide (Cu-SiCp) composites find its application as heat resistant and wear materials in electrical sliding contacts such as in electric switch, low dielectric constant dielectric layers in integrated circuits and wiring board where high electrical/thermal conductivity combined with good wear properties is required. In the present investigation SiC particle has been used for developing Cu-based MMCs. The main aim is to improve wear resistance and mechanical properties of Cu-SiCp metal matrix composite with minor loss of electrical conductivity. Cu-SiCp metal matrix composites containing 5,10 and 15 wt. % of silicon carbide have been prepared by Stir casting process. Wear, Hardness, Tensile strength experiments were carried out to examine the surface mechanical properties as well as the wear properties of the prepared composite. It has been observed that the reinforcement is distributed homogeneously all over the Cu-matrix and also composites have good bonding between the Cu-matrix and the reinforcement.Cu with SiC reinforced composite having 15% wt. fraction is found to exhibit best result.***

Keywords: MMCs, stir casting process, electrical conductivity, wear resistance

1. Introduction

In recent decades copper(Cu)is being a significant material, it has wide range of applicationsuch as in thermal and electronic fields like transmission wires, cables, generators, transportation vehicles, musical instruments,construction of buildings, roofs etc. Silicon Carbide is used as a semiconductor i.e. its conductivity is not as high as a good conductor and not as low as an insulator [7]. The limitation associated with copper is its poor ewar resistance and low strength. So in order to improve its strength related properties it is often alloyed or reinforced with suitable material to form a suitable composite to improve its mechanical other related properties. Generally reinforcing with SiC particles the Cu-matrix imparts high strength and also improves its wear properties to a large extent [8].

2. Literature Review

Thankachan and Prakash [1] have been experimented microstructural, mechanical and tribological behavior of Copper and Aluminum Nitride(AIN) by Stir casting Method and reported that microstructural observation confirms for the breaking down of grain size thus implying dynamic recrystallization process. Alsotensile strength increased with AlNvol%. The wear rate also decrease with respect to increase in reinforcement percentage while the average frictional coefficient value decreases.Hardness of the developed surface composite also increased.Bhat and Bourell [2] have been exhibited a higher wear resistance compared to the copper-110 alloy, while the copper–graphite coatings exhibited a very low coefficient of friction. Alaneme et al. [3] have been gave the result that theeffect of RHA/SiC weight ratio on the corrosion behaviour of the composites in 3.5% NaCl solution was not consistent for the different weight percent of reinforcement (5, 7.5, and 10 wt%) used in developing the Al–Mg–Si based composites. Fatoba et al.[4] have been revealed that with increasing volume fraction and particle sizes of the particulate had a significant effect on the thermal and electrical conductivity of the composites. Akramifard et al. [5] have been developed that the SiC particles improved the wear resistance of the composites and there was a rise in the average friction coefficient of pure Cu. Umale and Singh [6] have been studied that Copper – SiC (12%) composites relatively better abrasion resistance as compared to and Copper-SiO2 (9%) composites.

3. Experimental Analysis

3.1 Materials and composites Preparation

In this present investigation copper is used as the matrix material and SiC particles of size 220 mesh used as the reinforcements with different wt%. (5, 10, and 15wt%) in order to prepare three composites. To ensure uniform distribution of the reinforcements in the matrix the composites were fabricated by the liquid stir casting method. The Cu-SiCp composite was prepared by melting Cu at a temperature of 1400°C in a muffle furnace and then adding the preheated SiC as (5%,10%,15% by weight fraction) slowly with constant stirring under specific temperature. An electrical stirrer is used for stirring purpose. The stirring process is carried out about 15 minutes at 300rpm. After the complete mixing, the composite was poured into the split mould and allowed to solidify inside the mould at room temperature and taken out for machining to prepare test samples (Fig.2).

Figure 1: Molten material at pouring condition

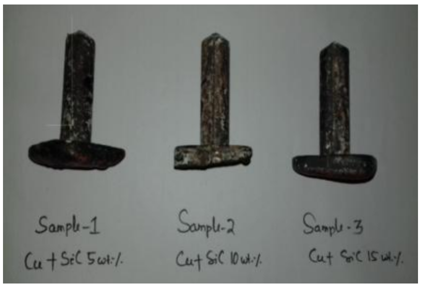

Figure 2: Pictorial view casting of samples

4. Experimental Procedure

4.1 Wear test

Under dry sliding condition on a pin on disc apparatus of model TE-100 (fig-3) the wear test was conducted. As the counter surface a steel disc was used and accordingto ASTM G99 standard, composites were made into pins having 10 mm diameter and 30 mm length by machining.The sliding material in the form of pin has been fixed on a holder, which has a provision for applying the load. A balance having an accuracy of 0.1 mg with a maximum weighing capacity of 400 g is used to find the mass of MMC Cu-SiCp pin. The pins were made to slide on the steel disc at 850, 600, and 400 rpm keeping the load constant (3.5 kg), and for constant time 5 min. After that the pins were made to slide on the steel disc for different loads of 2, 3.5, 5 and 7.5kg keeping the speed constant (850rpm), and at constant time of 5min. Again the pins were made to slide on the steel disc for different times of 5, 10, 15min at a constant load of 3.5kg and the speed remaining constant 850rpm.The wear was measured in the form of weight loss of the materials in gm and also in micron. The sample specimen used for wear testing is shownin Figure number 4.

Figure3: Pin on disc apparatus set up

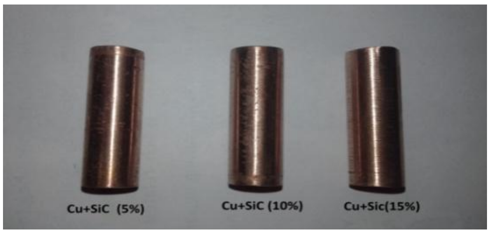

Figure4: Standard samples for wear test

4.2 Tensile test

The tensile strength of the specimens were carried out in the Universal Testing Machine of model BSUT- 40-JD manufactured by BLUE STAR ENGINEERING AND ELECTRONICS LTD. with load carrying capacity between 0.1 kN to 400 kN. As per the requirements of tensile testing standards of ASTM: E8, the samples were machined into a rectangular shape as shown in fig 5.

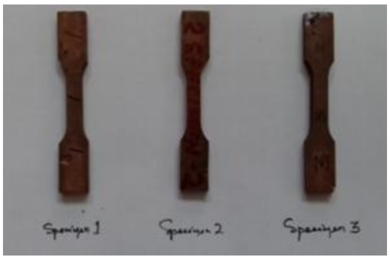

Figure 5: Standard samples for tensile test

4.3 Hardness test

In the present investigation the hardness value of the Cu-SiCp composites were observed on a micro hardness testing machine using the Vickers hardness scale. The sample preparation (fig.6) and testing procedure is conducted as per the ASTM E –92 standard. A diamond indenter which has a maximum load capacity of 50kg is used for measurement of hardness of the samples. A load of 5kgf was applied for 12 seconds.

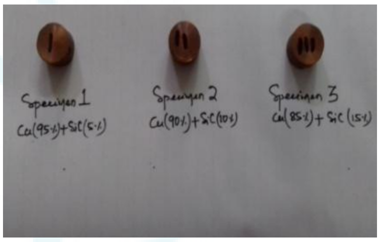

Figure6: Samples for Vickers hardness

5. Results and Discussion

5.1Wear test

The Weight losses of the composites obtained with varying loads, and constant speed (850rpm) and time (5 min) are shown in Table 1 and co-efficient of friction in table 2

Table 1: Weight losses for all sample with varying loads

Load in kgf	*Weight loss in grams*		
	Sample 1 (5% SiC)	*Sample 2 (10% SiC)*	*Sample 3 (15%SiC)*
2	0.0188	0.0072	0.0066
3.5	0.0160	0.0095	0.0106
5	0.0189	0.0221	0.0223
7.5	0.0363	0.0204	0.0290

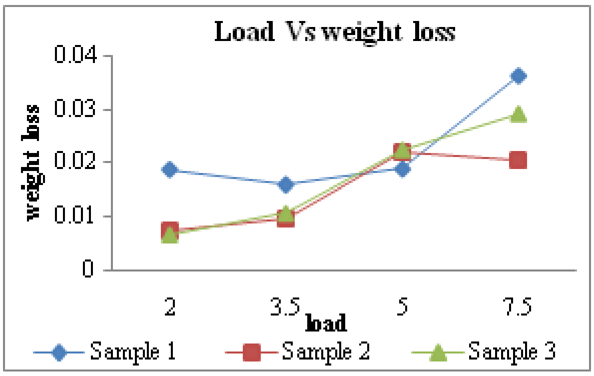

Figure 7: Weight losses for all sample Vs varying loads

From fig.7, it has been observed that weight loss was increased with increasing load. The sample-2 shows better result with composition 15% SiC, because of less weight loss with increasing load as compare to other two samples.

Table 2: Coefficient of friction for all sample with varying loads

Load in kgf	*Coefficient of friction*		
	Sample 1 (5% Sic)	*Sample 2 (10% SiC)*	*Sample 3 (15%SiC)*
2	0.54	0.67	0.57
3.5	0.52	0.56	0.21
5	0.51	0.46	0.53
7.5	0.49	0.48	0.51

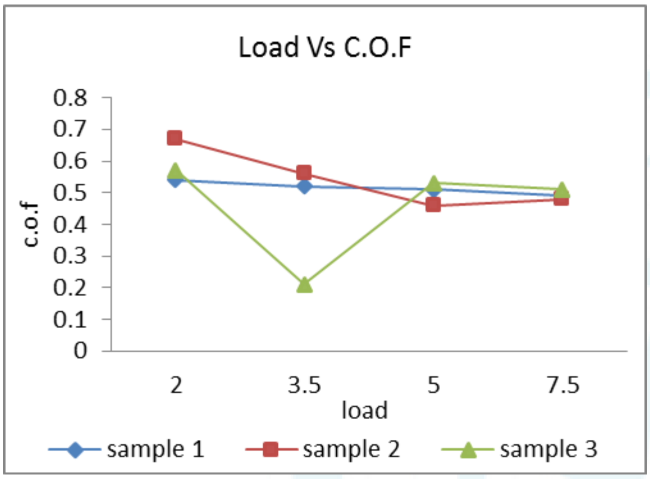

Figure 8: Coefficient of friction for all sample Vs varying loads.

From the fig.8 shows that the coefficient of friction of all samples with varying loads. The coefficient of friction of composites decreases as increase in percentage of SiC and sample 2 shows better results than other two samples that sample-3 have low C.O.F and sample-1 have high C.O.F

5.2 Tensile test

The Figure 9 shows the graphical representation of the data obtained from the tensile test. From the figure it is clear that the tensile strength of the composite containing 15 wt.% SiCp is higher(130MPa) than the composites containing 10 wt.% SiCp and (125MPa) and the composite containing 5 wt.% SiCp and (110MPa).

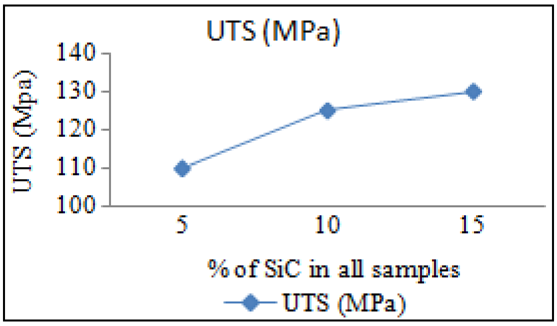

Figure 9: Ultimate tensile strength Vs % of SiC for all samples.

5.3 Hardness test

The results of the hardness of the composites reinforced with different wt% of SiCp in the Vicker's hardness scale is represented in Fig.10. The hardness of the composite containing 15 wt.% SiCp (115.75VHN) was found to be greater and the hardness of the composite containing 5 wt.% SiCp (77.89VHN) is the least amongst all.

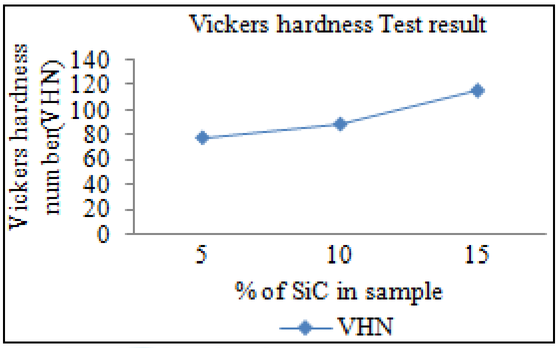

Figure 10: VHN Vs % of SiC in all samples

6. Conclusions

From the experimental data and results obtained the following conclusions may be drawn

1) It was found that weight loss was increased with increasing load. The sample-3 shows better result with composition 15% SiC, because of less weight loss with increasing load as compare to others.
2) The coefficient of friction for the specimen-1 is the highest may be due to the surface roughness and higher amount of silicon carbide present in the composite. However the coefficient of friction for specimen-3 i.e. with 15% SiC is the lowest in short run tests. It is also observed that sample 2 shows better results than other two samples.
3) 3.The tensile strength was observed to increase with increasing SiC particle content and it is significantly higher than the strength of the MMCs whereas the % of elongation of the MMCs produced are decreases rapidly as increasing wt. percentage of SiC particles in the matrix
4) It was observed that, the micro hardness increases as the composition of SiC increases.The vickers hardness of MMCs was found to be maximum (115.75 VHN) for sample number 3.
5) 5.Cu-SiC composite pins were manufactured by stir casting process. It was felt that the manufacturing of the pins is better done by compression moulding or injection moulding from the surface finish and mechanical strength point of view.The porosity can be reduced by constant stirring, maintaining the optimum melting temperature.

Therefore it was concluded from the experiments conducted, Cu with SiC reinforced composite having 15% wt. fraction is found to exhibit best result and recommended for engineering application.

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