Tribological characterization of Copper-Silicon Carbide composites produced by using Powder Metallurgy.

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Abstract:

Metal matrix composites are increasingly being employed in tribological sectors due to its intrinsic qualities, which include high stiffness, strength, and toughness. It was examined how silicon carbide and graphite reinforced copper-based metal matrix composites affected their tribological characteristics. Using the powder metallurgy route, silicon carbide having a particle size of 40 microns were reinforced in a copper matrix to create composite samples with 5, 10, and 15 volume%. The produced composite specimens were put through sliding wear testing utilizing a pin-on-disc method in accordance with ASTM G99.

The Taguchi methodology was used in the sliding wear trials, and the impact of wear parameters such applied weight, sliding speed, material composition, and sliding distance on the wear resistance of manufactured composites was evaluated using variance approach analysis. Additionally, the wear behavior of copper metal matrix composites was examined using signal-to-noise ratios. Tribological properties are improved when silicon carbide particles are injected into copper matrix material as reinforcement.

1. Introduction:

Metal matrix composites are gaining more importance in now a days because of their superior strength compare to the conventional materials. In majority applications convention materials are replacing with composites materials. Copper finds applications in many fields like construction, machinery, food preparations, jewelry and ductility, electrical properties, and thermal conductivity**[1-3]**. But when copper is used in its pure state its application is very limited because of low strength, high susceptibility to corrosion and cost associated is too high. In order to increase the strength and to decrease the cost ceramic particles are added into the pure copper material. Fiber-matrix interface bonding determines the interface's characteristics in composites. This bonding results from the characteristics of the reinforcement and matrix's surfaces **[4]**. Ceramic particle like SiC has the characteristics of high hardness, low wear resistance, excellent mechanical properties and high thermal conductivity **[5–9]**. The electrical conductivity of the composites is also influenced by the size of the SiC particles. As particle size grows, the electrical conductivity value rises because the addition of coarse particles to the copper matrix makes it easier for electrons to scatter, increasing the composite's conductivity **[10]**. Because of its superior wear resistance during sliding, the particulate metal matrix composite is primarily utilized in tribological applications. Gases and oil cannot be used because of the high temperatures that affect their self-lubricating qualities. Thus, a superior solid lubricant that functions throughout a broad temperature range is required **[11].**

Compared to traditional materials composites have unique properties that allow them to meet design requirements more affordably[13-15]. Because of these features its gaining more importance in developing this kind of material. The present work is based on developing a copper based metal matrix composites.

2. Material and fabrication technique:

Copper and SiC material was fabricated having a particle size of 40 microns. Powder metallurgy technique is used to fabricate the components [16-18]. The advantage of this technique is it always produces a component with a neat shape and eliminates the secondary machining process. Specimens are fabricated to length of 20 mm and having a diameter of 8 mm.

For the uniform distribution of the powder, proper mixing of powder is ensured. After that, based on the routine experiments load to be applied on die was fixed to 70 KN at ambient atmospheric temperature, then pressing from both top and bottom in Universal Testing Machine. Initially Green sintered components are produced and in order to impart the necessary strength and hardness it is subjected to sintering process. 7000C temperature is maintained for 7 hours and 4 hours normal Cooling is made. Temperature attained was 12ºC per minute. In the current work percentage of SiC is varied as per the weight percentage of powders. The below table shows the various composition of composite material.

Table 1: Various composition of composite material

Copper	Silicon Carbide
95	5
90	10
85	15

3. Experimentation:

Fabricated specimens are subjected to wear test under different conditions at room temperature. Pin on disc apparatus having a disc hardness of $65HR_C$ is used for the present study. Wear resistance is measured in terms of weight loss. Statistical tool like taguchi method is used to study the main effects and interactions. In order to analyze the wear resistance different parameters like load, speed, sliding distance and material compositions are considered. Based on the routine experiment the value of these parameters are fixed. The wear effects of the material composition, sliding speed, applied weight, and sliding distance on the composites were examined [19-24]. The below table shows the parameters and levels considered for Wear Test.

Table 2: parameters and levels considered for Wear Test

Factors	**L-1**	**L-2**	**L-3**
Composition of Material(M) Wt.%	5	10	15
Load (L) in Kg	1	2	3
Speed(S) RPM	200	400	600
Sliding Distance (D) in Meters	1000	2000	3000

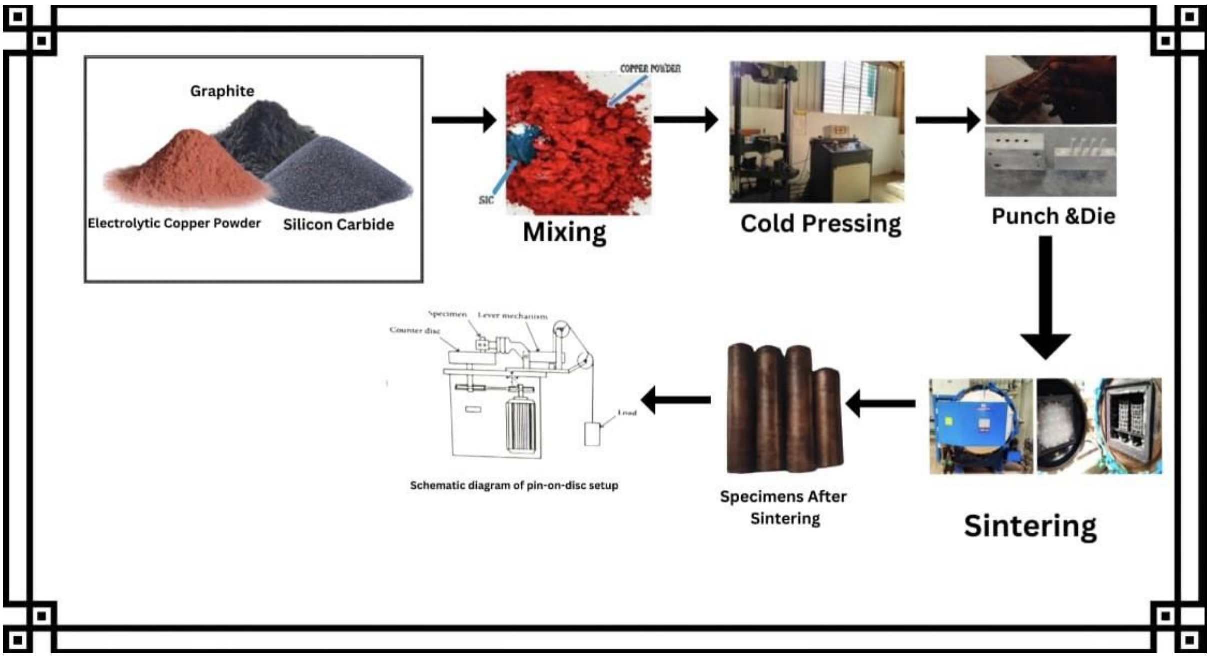

Figure 1: Process details of Powder Metallurgy

L27 orthogonal array is used to check the influence of the parameters and interaction among the parameters. The table 3 shows the orthogonal array of copper- sic samples.

Table 3: Orthogonal array of copper-SiC composites

Expt. No.	Material Composition-(M)	Load-(L)	Speed-(S)	Sliding Distance-(D)	W1 - W2	SN Ratio-(dB)	Mean
1	5	1	200	1000	0.0034	51.3727	0.00270
2	5	1	400	2000	0.0048	42.8534	0.00720
3	5	1	600	3000	0.0063	40.2646	0.00970
4	5	2	200	2000	0.005	44.7314	0.00580
5	5	2	400	3000	0.0065	48.6360	0.00370
6	5	2	600	1000	0.0054	41.1103	0.00880
7	5	3	200	3000	0.0064	42.9748	0.00710
8	5	3	400	1000	0.0062	28.1565	0.03910
9	5	3	600	2000	0.0068	60.0000	0.00100
10	10	1	200	1000	0.0027	51.7005	0.00260
11	10	1	400	2000	0.0042	42.9748	0.00710

12	10	1	600	3000	0.0057	40.3546	0.00960
13	10	2	200	2000	0.0045	44.8825	0.00570
14	10	2	400	2000	0.0045	44.8825	0.00360
15	10	2	600	1000	0.0048	41.2096	0.00870
16	10	3	200	3000	0.0058	43.0980	0.00700
17	10	3	400	1000	0.0049	28.1787	0.03900
18	10	3	600	2000	0.0063	61.2096	0.00087
19	15	1	200	1000	0.0021	52.0760	0.00249
20	15	1	400	2000	0.0034	43.9445	0.00635
21	15	1	600	3000	0.005	41.0415	0.00887
22	15	2	200	2000	0.0034	45.8486	0.00510
23	15	2	400	3000	0.005	49.9242	0.00319
24	15	2	600	1000	0.004	41.8625	0.00807
25	15	3	200	3000	0.005	43.8900	0.00639
26	15	3	400	1000	0.0042	28.9223	0.03580
27	15	3	600	2000	0.0056	51.3727	0.00270

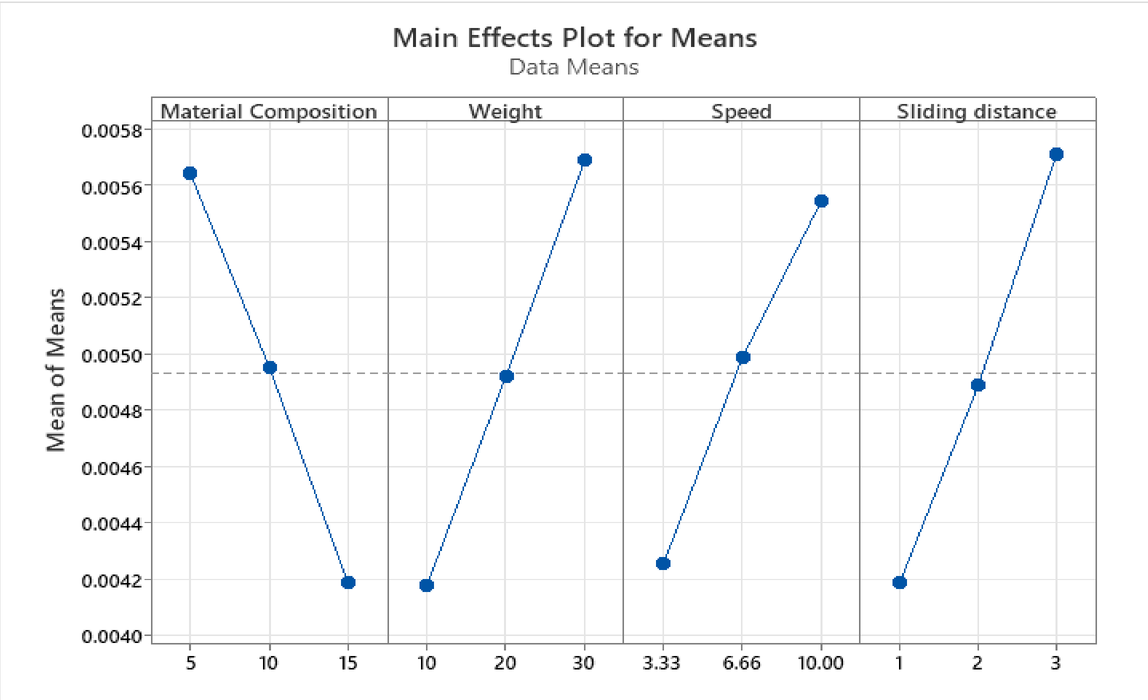

Figure 2: The plot of primary effects illustrates material loss as represented by S/N ratios

Table 4: Response Chart for Degradation of Material Signal to Noise Ratios

Level	Material Composition	Weight	Speed	Sliding distance
1	0.005644	0.004178	0.004256	0.004189
2	0.004956	0.004922	0.004989	0.004889
3	0.004189	0.005689	0.005544	0.005711
Delta	0.001456	0.001511	0.001289	0.001522
Rank	3	2	4	1

4. Result and Discussion:

The experiment shows that as the sliding speed increases from 200 rpm to 600 rpm, the surface becomes rougher. Since Cu composite is known to have less hardness than the steel disc's counter surface (HRC 65), plastic deformation occurs when Cu composites come into contact with rotating discs under different applied weight, such as 1kg, 2kg, and 3kg. The copper sample experiences abrasive wear as a result of increased metal-to-metal contact and plowing action caused by the hard counter surface's asperities. But at faster speeds (600 rpm) and greater sliding distances (3000 m), oxide layers like CuO and Cu_2O may form. SiC particle helps in improving the wear resistance because hard SiC particle support the stress on the contact surfaces and prevent the plastic deformation and abrasion occur, which reduce the worn of the material. The incorporation of ceramic particles in the composite results in the composite becoming harder, which further increases its resistance to penetration, and reduces subsequent material loss due to wear debris and other third-party particles found in the wear environment. Figure 3 shows that no interfacial product is formed at the interface, confirms that no reaction takes place between matrix and reinforcements during fabrication. From micro structural point of view, proper interfacial bonding is found between matrix and reinforcement. Therefore, the wear properties of Cu–SiC composites are greatly improved in comparison with those of copper. It shows better compatibility due to Negligible amount of pores.

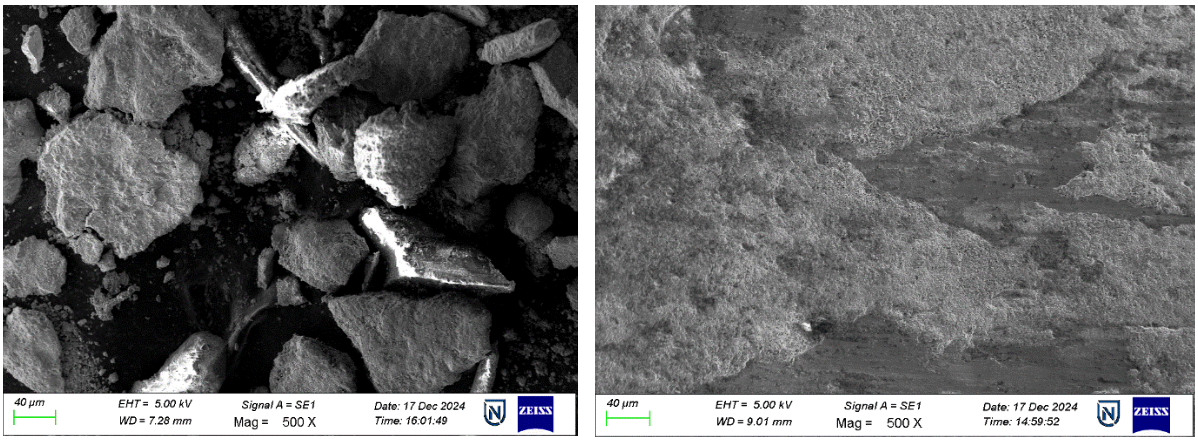

Figure 3: **SEM Image of worn out surface of SiC Copper composites**

Due to the increased metal to metal contact and ploughing action by the asperities of the hard counter surface, results in abrasive wear. As percentage of SiC in the composites increase, the overall hardness of the material rises and SiC particles act as hard barriers that impede the removal of softer matrix material and minimizes the plastic deformation of softer matrix material.

5. Conclusion:

- Cu SiC composites fabricated successfully through powder metallurgy technique.
- The wear test demonstrates that a decrease in wear track or depth is caused by an increase in the thickness of the cluttered graphite layer on the surface.
- It is seen that Cu - 15% SiC showed good wear resistance.
- The effective application of the Taguchi technique in creating experiments to examine the tribological characteristics of Cu-based hybrid composites is validated by the confirmation test results, which display a low error

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SiCp-reinforced aluminium metal matrix composite (Al/SiCp–MMC) by vacuum brazing" Composites: Part A 30 (1999) 823–827
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