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Tribological Properties of Boron Carbide Reinforced Copper Based Composites

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Abstract

In this study, a boron carbide (B4C) reinforced copper based Metal Matrix Composites (MMCs) manufactured by powder metallurgy method and tribological behavior of compacted composites were investigated. B4C reinforcement was selected at different ratio from 2%wt to 10%wt. Powders was compacted under 735±1 MPa pressure in a die with cold pressing method. Sintering of the samples was performed at two different sintering time as 1 hour and 3 hours under Ar gas atmosphere at 900 °C. Tribological tests were performed by using a computer aided pin-on-disc experimental setup under dry sliding conditions. Tribological tests were performed from 1 hour to 5 hours. And wearing surfaces were investigated in a Scanning Electron Microscope SEM) and mechanisms of the wear were detected. In addition to that tribological behavior and porosity properties of the manufactured samples were investigated. It was found that the porosity of the samples was increased with increasing B4C content. Nevertheless, wear resistivity increased with increasing reinforcement content.

Key words

Metal Matrix Composites (MMC's), B4C, Tribology, Copper Based Composites

1. INTRODUCTION

Because of the unique properties of the Metal Matrix Composites (MMCs) have many application in industry [1, 2]. Most of the studies in industrial components should have good mechanical properties with better tribological properties [3]. The need for a recent wear resistant material for high performance tribological applications has been one of the major propellant power for the tribological development of ceramic particulate reinforced materials [4]. The introduction of hard, non-deformable ceramic particles into matrix alloy causes a loss in ductility and toughness of MMCs [5]. But the optimum ratio usage of the reinforcement particles could assist wear performance with a toughness. Matrix materials of the MMCs generally selected for their high thermal conductivity and ductility properties as copper, nickel and aluminum [6]. And reinforcement materials should be harder than matrix for the supporting the structure of composite as SiC, B4C Si3N4, Al2O3 and TiC [7].

In this study, copper and B4C was selected as a matrix and reinforcement materials, respectively. Copper-based materials are widely used in many industrial applications because of their good wear resistance and friction ductility, remarkable corrosion resistance, as well as self-lubrication properties, such as sliding bearings, sleeves, brushes and other components [8-10]. B4C reinforcement material was selected for its tribological and mechanical properties [4, 11]. Moreover, B4C particles have high impact and wear, low density, high melting point, and excellent resistance to chemical agents as well as high capability for neutron absorption make boron carbide attracting much attention as an acceptable reinforcement [12].

Wear and friction are the common problem in industry [13, 14]. And wear shows itself in two different way, abrasive and adhesive. [15, 16]. Adhesive wear cause surface deformation with separation of the surface by layers but the abrasive wear cause separation of the particles from surface by scratching [17]. Main motivation and the novelty of the study was determine of the wearing performance of the Cu-B4C MMCs with a pin-on-disc wearing test machine.

2. EXPERIMENTAL DETAILS

In this study, MMCs was manufactured. Copper as matrix and boron carbide (B4C) as reinforcement were selected at different ration (2%, 4%, 6%, 8% and 10%). 0,1mg precisions balance was used for weighting operations. Composites were mixed about 8-10 min. with mechanically. Mold was lubricated with a solid lubricant before molding. Manufacturing parameters and wearing parameter was given Table 1.

Table 1. Manufacturing and wearing parameters.

	Sintering Time (h)	Molding Pressure (MPa)	Sintering Temperature (ºC)	Wearing Time (h)	Wearing Load (N)
Cupper (pure)	1	735	900	-	-
	3				
Composites (2%, 4%, 6%, 8% and 10%)	1			1-5	50 ±5
	3				

Samples were sintered at 900 ºC. Argon atmosphere were selected for preventing the dirtiness during sintering process. Different sintering time and molding pressure were applied. Hardness of the samples was measured with Brinell Hardness method. Porosity of the samples was calculated with experimentally.

Samples experimental density was measured with formula 1.

$$\rho=m/V \quad (1)$$

Where, ρ (g/cm3) density, m (g) mass and V (cm3) volume. Composites theoretical density was calculated with formula 2.

$$\rho T= [(\%\ wt\ Cu\ .\ \rho\ 1\ )+ (\%\ wt\ B4C.\ \rho\ 2)] \quad (2)$$

Where, ρT theoretical density, wt (g) mass, ρ1 and ρ2 (g/cm3) copper and B4C densities. Then formula 3 can be used for calculate the porosity of the samples.

$$\%\ porozite = (\Delta\rho/\rho 0)x100 \quad (3)$$

Where, Δρ difference between theoretical density and experimental density, ρ0 theoretical density.

Pin-on-disc wear method was run for wearing process. Samples were cut suitable for sample (pin) holder about 10mm x 10mm x40mm. Pin track diameter was selected as 100 mm. with 100 rpm working speed (≈0,5m/s). Cold work tool steel disc was used for wearing. Running in process was applied before wearing. Running in and experiments were carried out 50±5 N load.

3. RESULT AND DISCUSSION

3.1. 3.1. Structural Investigation

Structural investigations of the composites were performed with a Leica named optical system and the images of the structures were given in Figure 1. Figures show the different reinforcement ratio of the B4C.

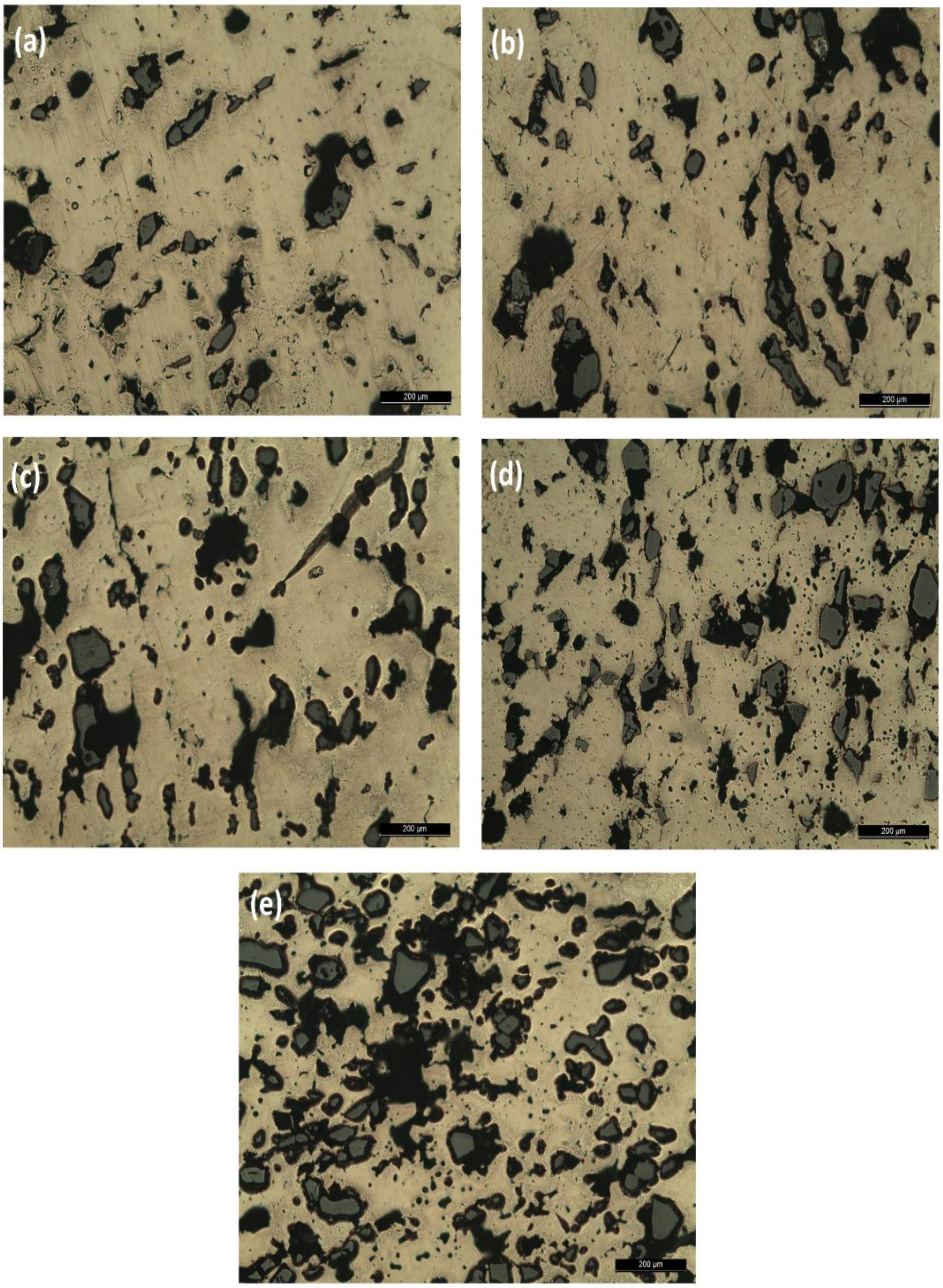

Figure 1. Optical microscope images of the composites (1 hour sintering time)(a-2%, b-4%, c-6%, d-8%, e-10%) (10x)

Investigated macrostructure images show that the effect of reinforcement. Images show that porosity (dark areas) was increased with increasing reinforcement B4C particles (grey areas).

3.2. SEM Investigation

Scanning Electron Microscope (SEM) investigations was imaged after wear tests. And Figure 2 shows the worn surface of the composites under dry sliding conditions.

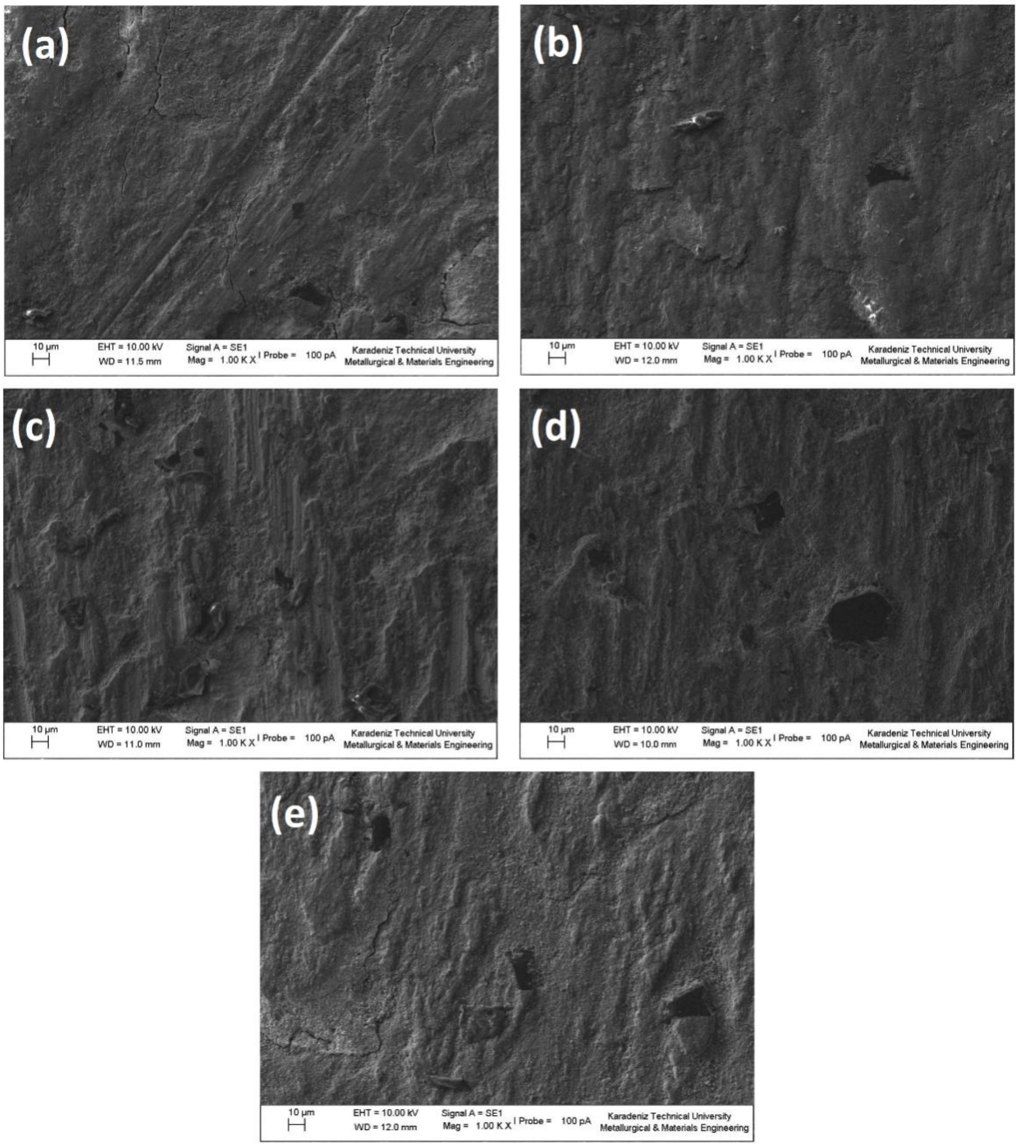

Figure 2. Worn surface of the composites which was manufactured with 1 hour sintering time (a-2%, b-4%, c-6%, d-8%, e-10%) (1000x)

3.3. Porosity

Porosity of the samples was calculated with formulas 1, 2 and 3. The graphical explanation was given in Figure 3.

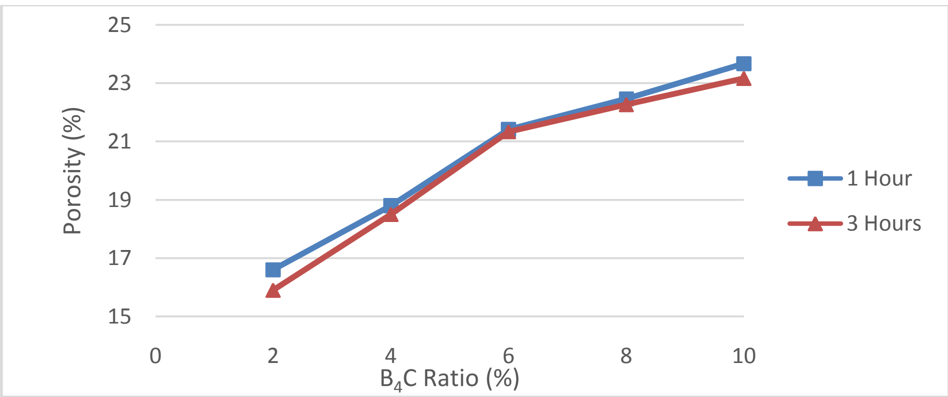

Figure 3. Porosity ratio of the samples

Porosity of the samples was increased with the increasing reinforcement ratio. And pure compacted copper porosity was calculated as 10.05%

3.4. Hardness

Hardness of the samples was measured with Brinell Hardness test method. And the hardness of the samples was given in Table 4.

Table 2. Hardness value of the samples

Sample	HB 1 hour sintering time	HB 3 hour sintering time
Pure compacted copper	32	24
2 %	42	33
4 %	51	53
6 %	53	55
8 %	56	84
10 %	57	86

3.5. Wear Loss

The wear investigation of the samples was performed under dry sliding conditions. Wear loss was measured hour by hour and mass loss was found. Finding of the mass loss was converted to the wear rate. Wear rate formula was given in Formula 4.

Wear Rate ($mm^3 m^{-1}$) = mass loss (g) / [density (g/mm^3) x sliding distance (m)] (4)

With the conversion of mass loss to the wear rate Figure 4 and 5 was obtained.

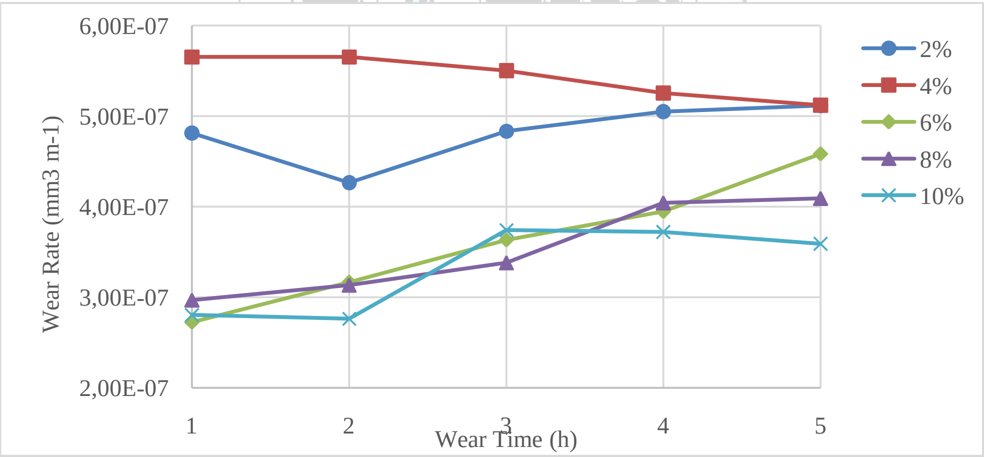

Figure 4.Effect of the sintering time to the wear rate (1 h sintering time)

Average wear rate of the samples was showed that minimum wear rate for 10% reinforced sample. 2% and 4% samples was showed higher wear rate and the ratio of the wear was decreased with increasing wear time. By the contrast with, samples which was reinforced in proportion as 6%, 8%, 10% showed that increasing wear rate with the increasing wear time. It means, B_4C particles was removed from surface with the vibration and cause some deep scratching and erosion.

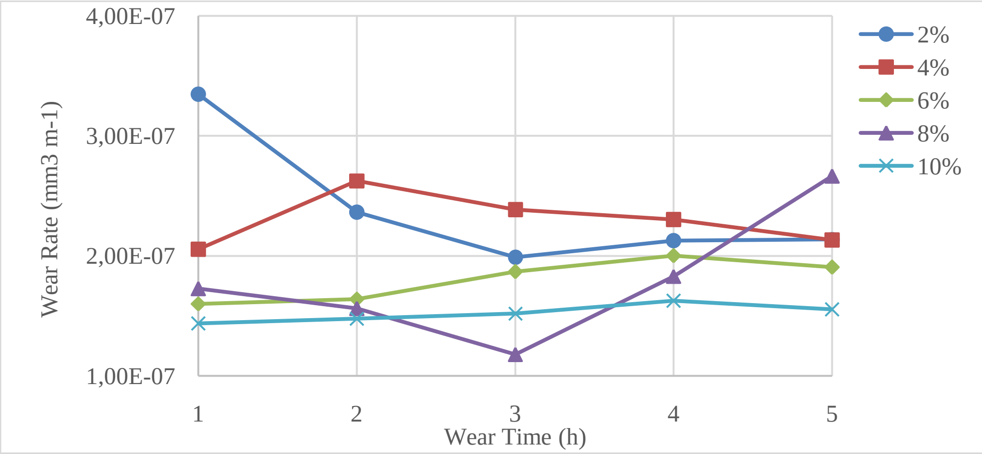

Figure 5. Effect of the sintering time to the wear rate (3 h sintering time)

Figure 5 shows that the sintering effect on the samples and it was detected decreasing wear rate with increasing sintering time. Average wear rate was showed minimum wear rate for 10% reinforced sample as Figure 4. But the average wear rate was less than Figure 4 about almost 46%. And all samples difference was less according the 1 hour sintered. Also Figure 3 showed that sintering effect on porosity. So increasing sintering time cause less pore, high hardness and high wear resistivity.

4. CONCLUSIONS

Copper and B_4C reinforced copper based metal matrix composites was manufactured with different sintering time. Hardness and porosity measurement was performed for all samples. But tribological tests was applied for the composites and the conclusion was found:

1.) Porosity of the composites were increased with increasing reinforcement ratio.

2.) Hardness of the composites were increased with increasing sintering time.

3.) Wear loss was decreased with increasing sintering time.

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