Special Issue of the 8th International Advances in Applied Physics and Materials Science Congress (APMAS 2018)

Influence of Nano-WC Addition on Wear Performances of Cu–Ni Matrix Nanocomposites

H. Cug[a,*], H. Demirtas[b], M.A. Erden[a], Y. Akgul[c], M.E. Turan[c] and O. Zengin[a]

[a]Karabuk University, Department of Mechanical Engineering, Karabuk, Turkey

[b]Karabuk University, TOBB Tech. Sciences Vocational School, Karabuk, Turkey

[c]Karabuk University, Department of Metallurgical and Materials Engineering, Karabuk, Turkey

The present study focuses on the effect of tungsten carbide content on wear behavior of Cu based composites which are generally preferred in engineering applications. Nickel 4 wt% was used as the binding agent in order to develop wetting ability between matrix and reinforcement. Cu-4Ni matrix composites were fabricated via powder metallurgy incorporating the different amount of present study focuses on the effect of tungsten carbide (0.5, 1 and 2 wt%). Wear tests were conducted using three different loads (5 N, 10 N and 20 N) in dry sliding conditions. Results showed that hardness of the composites increased with increasing tungsten carbide content. Tungsten carbide additions also lead to improving the wear resistance of copper matrix composites. Abrasive wear mechanism was generally observed for all samples especially for higher loads according to the scanning electron microscope (SEM) results

DOI: 10.12693/APhysPolA.135.892

PACS/topics: powder metallurgy, copper, tungsten carbide, wear, nickel

1. Introduction

Copper and its alloys are widely used because of their electrical, thermal and corrosion properties [1]. However, the applications of copper and alloys are often limited by their low mechanical properties compared to steel, aluminum or nickel. Metal matrix composites reinforced with nanoparticles have been developed to improve the mechanical properties and wear resistance of various alloys [2]. Tungsten carbide cements are widely used in fields requiring high hardness, abrasion resistance and good strength [3]. WC is used in Cu alloys because of the good wetting at the interface and the absence of intermetallic phases [4]. In this paper, Cu4Ni/WC powders were mixed by turbula mixing and composites incorporating the different amount of WC (0.5, 1 and 2 wt%) were synthesized by powder metallurgy technique. The effect of nano tungsten carbide (WC) particles on microstructure, wear performance and hardness of Cu-4Ni/WC nano composites were investigated.

2. Experimental procedure

Copper powder (99.9% purity and 40–50 μm size ranges), nickel powder (99.9% purity and 40–50 μm size ranges) and tungsten carbide powder (99.9% purity and 50–60 nm size ranges) were purchased from Nanografi Co. Ltd. in Turkey. Composites were fabricated by powder metallurgy technique after turbula mixing. Turbula mixing was performed at 200 rpm for 120 min. Then, the composite powder was pressed under 500 MPa pressure. Sintering process was carried out on the same device at 900 °C for 2 h at argon atmosphere. Grinding with different grade silicon carbide (SiC) grit papers and polishing process with 3 μm and 1 μm diamond suspensions were applied for microstructure analysis. Field emission scanning electron microscope (Carl Zeiss Ultra Plus) equipped with EDX was used to examine the microstructure of composite. Experimental densities of specimens were calculated according to the Archimedean principle. Samples were weighed in air and then immersed in alcohol. Vickers microhardness tests were performed for the produced composites using 300 g of loading and 15 s of dwelling time. UTS Tribometer Test Machine in a reciprocating contact configuration was used to examine wear properties at 20–25 °C temperature and the relative humidity of 30–45%. The wear tests were carried out for all samples under loads of 5 N, 10 N and 20 N. Sliding speeds were chosen as 150 mm/s. The sliding distance was kept constant as 1000 m.

3. Results and discussion

As the ratio of the reinforcement material increases, it is observed that the concentration of particles in the matrix increase. However, as shown in Fig. 1 when the reinforcement amount increased up to 2%, agglomeration was begun.

Also, this agglomeration can be seen from mapping analysis. As shown in Fig. 1e, f, compared to 1 wt% WC reinforced composite, there is partly agglomeration for 2 wt% WC reinforced composite. Five measurements were taken for each sample and average of hardness and density results belonging to the composites are presented in Table I. There is a slight decrease in density with the increase of the reinforcement amount. This is due to the adverse effect of WC nanoparticles on compressibility [5].

*corresponding author; e-mail: hcug@karabuk.edu.tr

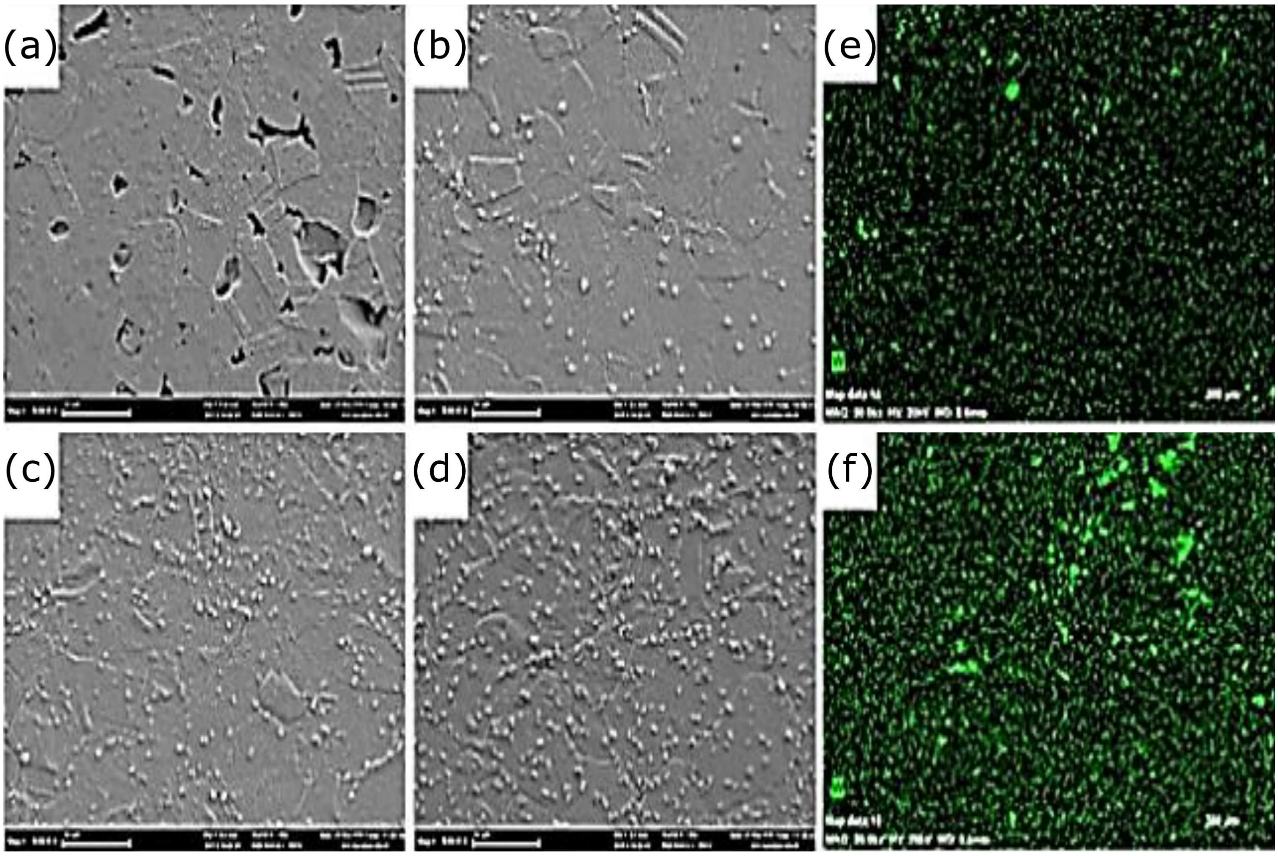

Fig. 1. SEM images of (a) pure Cu, (b) 0.5 wt% WC, (c) 1.0 wt% WC, (d) 2.0 wt% WC, (e) SEM mapping of 1 wt% WC, (f) SEM mapping of 2 wt% WC reinforced composites.

Hardness performance is improved significantly with the addition of WC nanoparticles. This is because there is an obstacle of dislocation movement by harder reinforcements. However, there is slightly increase after 1 wt% WC content. This is because agglomerations of WC particles at grain boundaries which can be seen in Fig. 1f can cause weak chemical bonding between aluminum and reinforcement material. Harder reinforcements in matrix affect also wear performance of materials. Cu-4Ni-1WC exhibits lowest wear rate as shown in Fig. 2a among the specimens. WC reinforcement may show lubricant effect. When the reinforcement content increases up to 2 wt%, wear rate increases because of agglomerations. When applied loads increase, coefficient of friction (COF) generally decreases according to the Fig. 2b. Cu-4Ni-1WC exhibits lowest COF under load of 20 N due to the existence of harder reinforcement in material.

TABLE I

Density and hardness results of composites

WC content	Density [gr/cm^3]	Hardness [HV]
0	6.8869	22 ± 1.1
0.5	6.6526	27 ± 1.3
1	6.7646	30.3 ± 1.0
2	6.3993	29.7 ± 0.9

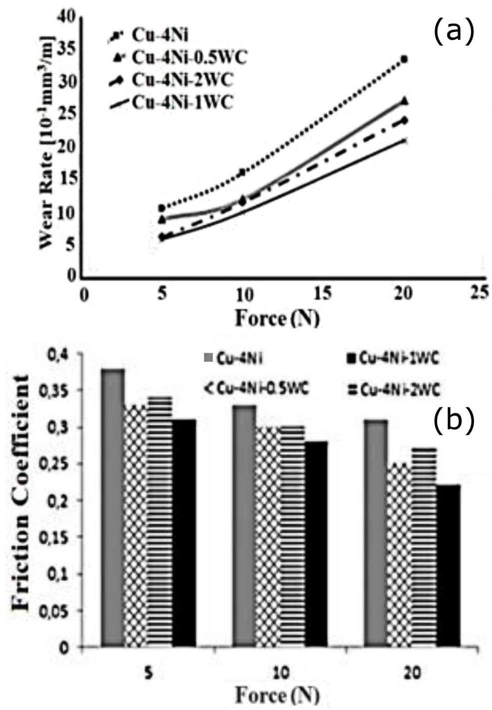

Fig. 2. Force–wear rate (a) and force–friction coefficient (b) graphics respectively.

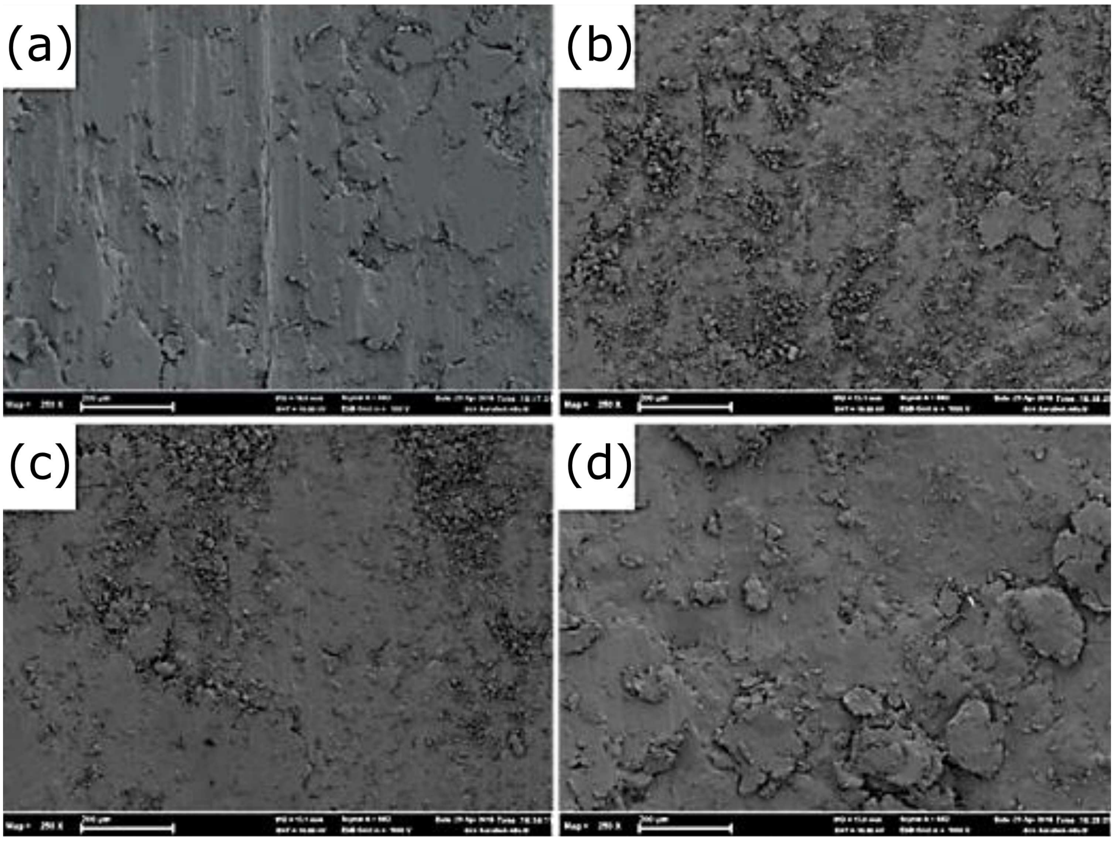

Fig. 3. SEM images of worn surfaces of (a) pure Cu (b) 0.5 wt% WC (c) 1.0 wt% WC (d) 2.0 wt% WC under load of 20 N.

Figure 3 shows that worn surfaces of unreinforced Cu-4Ni and WC reinforced composites. Scratches can be clearly seen for unreinforced sample. Thus, abrasive wear is a dominant mechanism for this sample. Once WC incorporated to the matrix, wear resistance of Cu–4Ni improves which can be related to lubricant properties of nano powders.

4. Conclusion

Samples were fabricated by powder metallurgy successfully. Homogeneous distribution of reinforcement was achieved up to 1 wt% addition. However, there is an agglomeration which affects mechanical properties negatively for Cu-4Ni-2WC. Hardness and wear performance of samples increase with the addition of WC. COF generally decreases in higher applied loads. Cu-4Ni-1 wt% WC shows the best wear performance among the samples.

Acknowledgments

This work is supported by the Scientific Research Projects of Karabuk University (Grant No: KBÜBAP-18-YL-004) in Turkey.

References

[1] V. Nadkarni, in: *High Conductivity Copper and Aluminum Alloys*, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York 1984.

[2] S. Bathula, M. Saravanan, A. Dhar, *J. Mat. Sci. Tech.* **28**, 969 (2012).

[3] E. Hong, B. Kaplin, T. You, M.S. Suh, Y.S. Kim, H. Choe, *Wear* **270**, 591 (2011).

[4] P.K. Deshpande, J.H. Li, R.Y. Lin, *Mater. Sci. Eng. A* **429**, 58 (2006).

[5] A. Pakdel, A. Witecka, G. Rydzek, D.N.A. Shri, *Mat. Des.* **119**, 225 (2017).