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An Investigation of the Wear Behaviours of Nano Al_2O_3 Particle Reinforced Cu Composites

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In this study the effect of nano Al_2O_3 amount on the wear behaviours of Cu–nano Al_2O_3 composites, produced by powder metallurgy method, was investigated. In the scope of the study five different amounts of nano Al_2O_3 (0.5%, 1.0%, 1.5%, 2.0 %, 2.5%) were added into pure Cu powders and mechanically milled for 240 min. The mechanically milled Cu–Al_2O_3 powders were pre-shaped by cold press under 600 MPa load. Pre-shaped samples were sintered in atmosphere-controlled furnace at 1000 °C for 1 h. Microstructure examinations, hardness measurements, and wear tests were carried out. In this study the hardness values were found to have decreased with increasing Al_2O_3 amount. Wear test results were compatible with hardness results. The highest weight loss was measured with 2.5% Al_2O_3 content.

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PACS/topics: nano Al_2O_3, Cu, hardness, wear behaviour, powder metallurgy

1. Introduction

Nanocomposites, which are produced by adding nanoreinforcement elements to metal matrix composites, are promising materials for a variety of uses due to their superior mechanical properties [1, 2]. The nanoreinforcement element that stands out the most is carbon nanotube. In addition to carbon nanotube, reinforcement elements such as nano SiC, nano Al_2O_3, and nano B_4C are also used in production of nano aluminum composites [3–5]. Al and alloys are preferred as matrix materials in nanocomposites due to their properties such as low density and high corrosion resistance. In addition to Al and alloys, matrix materials used in nanocomposites include metals such as Cu, Mg, and Ti [6–8]. The most common problem encountered in relation to nanocomposites is agglomeration as a result of non-homogeneous distribution of the reinforcement element within the matrix. The expected improvement in the mechanical strength of the composite does not occur due to this agglomeration [6, 9]. Low wettability of reinforcement elements used in metal matrix composites and non-homogeneous distribution of reinforcement elements within the matrix make it quite difficult to produce metal matrix nanocomposites using liquid production methods (casting, infiltration). The most widely preferred method in production of metal matrix nanocomposites is the mechanical alloy/mechanical milling (MA/MM) method, which is a powder metallurgy method. This method is a solid-state production method, and involves mixing the metal powder, which is the matrix material, with the reinforcement element in a high-energy mill. Also, undesired reactions between the matrix material and the reinforcement element seen in liquid methods are prevented with the use of this method, and the reinforcement phase is distributed more homogeneously within the structure [9–12]. For this reason, this study investigates microstructure, hardness, and wear behaviors of composites produced using the mechanical milling method by adding different amounts of nano Al_2O_3 to pure Cu.

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2. Materials and equipments

In this study, commercially acquired pure copper (99%) powder was used as matrix material. Aluminum composites were produced by adding different amounts of nano Al_2O_3 (0.5%, 1%, 1.5%, 2%, and 2.5%). Nano Al_2O_3 powders were added to pure Cu powder, and were milled within a stainless-steel chamber for 240 min using a MA/MM device. MM operations were performed using a Fritsch brand device at 400 rpm and with 10:1 ball-powder ratio. 1% stearic acid was used as the process control agent. In order to prevent powders from overheating during MM operations, the device was paused for 10 min after each 20 min milling interval. Mechanically milled composite powders were cold-pressed (600 MPa) in a mold to obtain preformed samples 12 mm in diameter and 7 mm in height. Preformed green compacts were sintered in an atmosphere-controlled furnace at 1000 °C for 1 h. Following standard metallographic processes, sintered samples were etched with Keller's solution, and examined under scanning electron microscope. Hardness measurements were performed using a microhardness measurement device. Wear tests were performed using a pin-on disc-type wear testing device with 1 ms^{-1} sliding speed, 30 N load, and four different sliding distances (500, 1000, 1500, and 2000 m).

3. Results and discussion

Figure 1a and b shows hardness changes and weight loss values after wear tests for aluminum composites produced by adding different amounts of nano Al_2O_3 to pure copper. As shown in Fig. 1a, the lowest hardness value was measured for pure Cu samples, whereas the highest hardness value was measured for composites produced by adding 0.5% nano Al_2O_3 to pure Cu. The addition of more than 0.5% nano Al_2O_3 led to a decrease in the hardness value of composites. The reason behind this decrease, as shown in microstructure SEM images given in Fig. 2 as well, is the agglomeration and non-homogeneous distribution of the reinforcement phase within the structure due to increasing nano Al_2O_3 amount. In a previous study, it was reported that agglomeration reduced mechanical strength in composites produced using nanoreinforcement elements [6]. As shown in Fig. 1b, the highest weight loss, as a result of wear tests performed under 30 N load, was measured for pure Cu samples, whereas the highest weight loss was measured for composites produced by adding 2.5% nano Al_2O_3 to pure Cu. Weight loss values of composites were produced by adding different amounts of nano Al_2O_3 to pure copper showed variances, and did not support the hardness results given in Fig. 1a. The reason behind this is believed to be the inconsistent weight loss as a result of local fractures (because of failure to create the necessary bond between the matrix and the reinforcement element) in samples during wear tests due to the agglomeration of the reinforcement phase in the microstructure, Al_2O_3, to pure copper.

As shown in microstructure SEM images given in Fig. 2a–f, a more non-homogeneous distribution was observed with increasing nano Al_2O_3 amount, and the agglomeration of the reinforcement phase in specific zones was evident. The agglomeration issue is frequently encountered in nanocomposites due to the size difference between the matrix and the reinforcement phase. This agglomeration was reported to reduce the mechanical strength of the structure in previous studies [6].

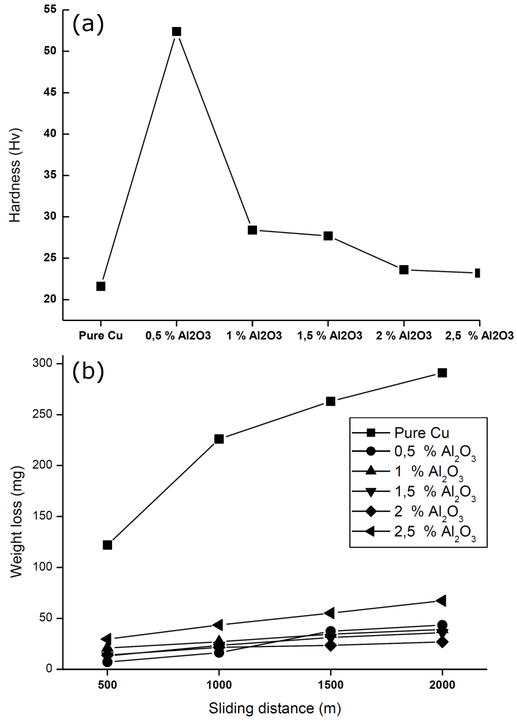

Fig. 1. Hardness changes and weight loss values for composites produced by adding different amounts of nano Al_2O_3 to pure copper. (a) Hardness values, (b) weight loss.

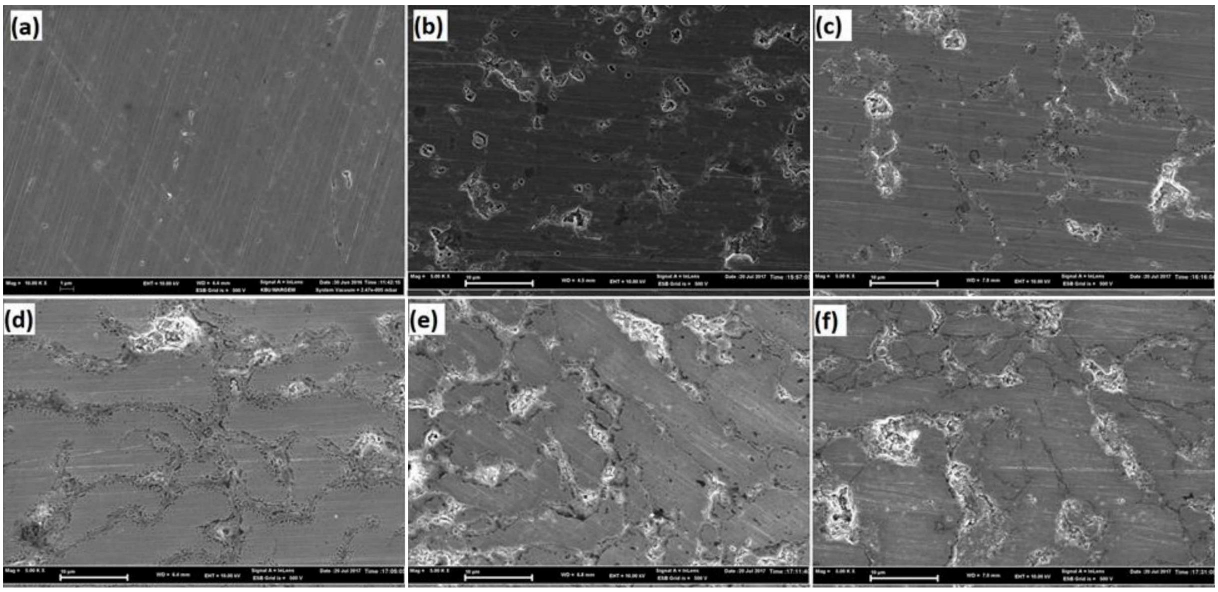

Fig. 2. SEM images of aluminum composites produced by adding different amounts of nano Al_2O_3 to pure copper. (a) Pure Cu, (b) 0.5%, (c) 1%, (d) 1.5%, (e) 2%, and (f) 2.5%.

4. Conclusion

Below are the results of the present study which investigates the effects of the nano Al2O3 amount on the wear behaviors of Cu-based composites. Al_2O_3 concentrated in specific zones and the agglomeration increased with the increasing nano Al_2O_3 amount in composites produced by adding different amounts of nano Al_2O_3 to Cu. As a result of the hardness measurements, the highest hardness value was measured for composites produced by adding 0.5% nano Al_2O_3 to pure Cu, while a decrease in hardness was observed with increasing nano Al_2O_3 amount due to agglomeration.

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