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Characterization, pore size measurement and wear model of a sintered Cu–W nano composite using radial basis functional neural network

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ABSTRACT

Cu–(5–20%) W composite preforms, with a density of 94% were prepared through mechanical milling, mixing, compaction, sintering and hot extrusion. The X-ray Diffraction analysis, Particle Size analysis, Transmission Electron Microscope, Scanning Electron Microscope and Energy Dispersive Spectrum were used for the characterization studies. The pore size during different sintering atmospheres and the pore size reduction during extrusion, were studied through Auto CAD 2010 software. The wear experiments were conducted using the pin-on-disc wear tester. The various regions in the wear mechanisms were identified through the wear distribution map. The Radial Basis Functional Neural Network has been used in an attempt to predict the mechanical and tribological behavior of composites, and useful conclusions have been made.

1. Introduction

The poor wear resistance of copper (Cu) makes it unsuitable for heavy duty applications particularly in electrical sliding contacts. The Cu matrix composites benefit from the wear resistance of the reinforcement such as W, due to some other good ceramic reinforcement components. W is well known for its better wettability and improved tribological property without affecting the electrical conductivity of Cu, due to its very high melting point [1]. Copper–tungsten (Cu–W) composites are extensively used for their superior strength at high temperature and wear resistance, for electrical discharge, electrode materials, relay blades and electrical contact supports [2]. The Powder Metallurgy (P/M) method is a low cost method, suitable for high volume production of complicated shapes. It is widely used for the manufacturing of Cu–W materials. The P/M processing includes mixing, pressing and sintering [3,4]. One of the advantages of P/M when compared to casting is having better control on the microstructure and better distribution of the reinforcement is possible in P/M compacts, but P/M processed composite always have pores [1,5]. In conventional sintering, an external source of heat and radiation are used to heat green compacts [6,7]. Conventionally sintered P/M products exhibit some porosity and coarser microstructure [8]. It affects the physical and mechanical properties of the products and the study of pore measurement is mainly focused on, in this article [9]. Hot pressing and extrusion of powder composite is a more effective consolidation method for producing particulate composites with good densification, than any other producing techniques because of its improved wettability, which gives sound parts without pores [10]. The mechanical and electrical properties of the composites have been found to have improved considerably due to the dispersion of the nanometer sized W particles in the Cu matrix by P/M and the extrusion process [2,11]. Wear resistance is an important factor for various engineering applications for the better performances. Although the friction and wear properties of the Cu based composites in dry sliding wear conditions are widely investigated, such understanding in Cu–W compacts are very limited [1,2,12].

The soft-computing tool Artificial Neural Network (ANN) is a tolerant of imprecision, uncertainty, partial truth, and approximation in designing models, which can process the material parameters to predict the properties of P/M data [13]. Neural networks have been proven to be highly flexible modeling tools, for learning the mathematical model between input variables and output responses for nonlinear systems [14]. The neural network was

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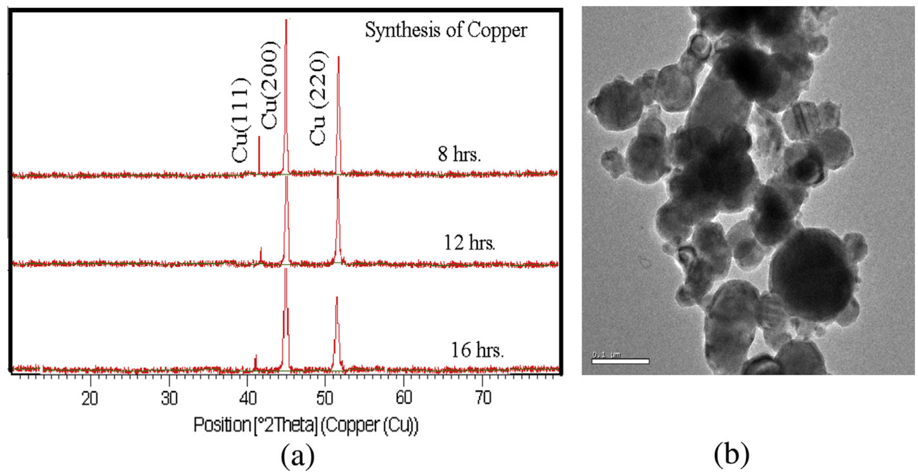

Fig. 1. (a) XRD patten of Cu particles at different hours during mechanical milling and (b) TEM image of Cu particles after 16 h.

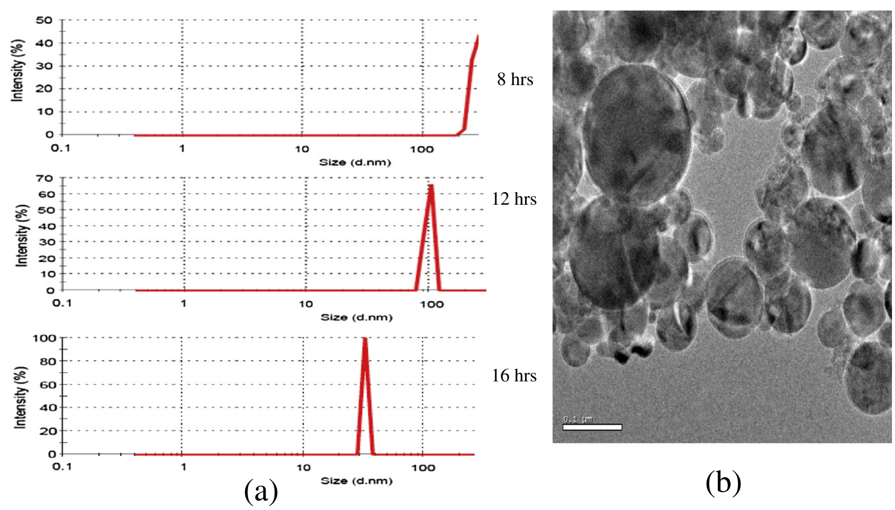

Fig. 2. (a) Particle size analyzer image of W particles at different hours during mechanical milling and (b) TEM image of W particles after 16 h.

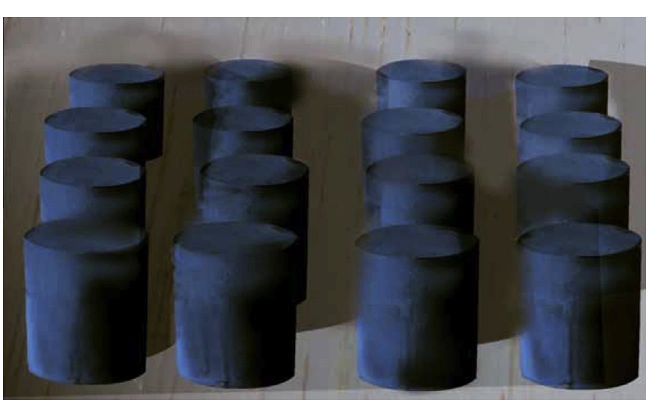

Fig. 3. Sintered specimens.

extensively used by many researchers to predict the physical, mechanical and the tribological properties of composite materials [15,16]. Many literatures pointed out that the ANN approach is a successful analytical tool that can be used to predict the wear behavior of new materials and composites, and concluded that the ANN is a good analytical tool to predict the wear properties [17,18]. Many researchers have attempted to use soft computing tool like neural network for various applications in manufacturing such as tool wear, TTT diagram prediction, optimization of powder packing density, P/M process modeling, turning force prediction and on-line monitoring [19–23]. Rasheed and Mahmoud [24] evaluated the predicted effect of wear resistance using the NN model with low error. Accordingly, the interpretation of wear behavior requires a lot of experimental data obtained from the different series of tests [25].

Literatures confirm that very few works have been predicted through the Radial Basis Function Neural Network (RBFNN). It is an extensive application in time series predictions with less data [26]. They are the object of continuous research and improvements in RBFNN learning and modeling [27,28]. A different basis functions like Standard Gaussian, thin-plate spline, multi quadratic, inverse multi quadratic, and Cauchy have been proposed for hidden layer nodes. The standard Gaussian function is one of the most commonly selected methodologies. Compared to other types of ANN, the RBFNN requires less computational time [29]. RBFNNs have been applied in the area of ANN, and use as a placement of the sigmoidal unit in Back Propagation NN to reduce the error [30].

Wear is a system-dependent property and therefore, the friction and wear properties depend on the operating environment, load, sliding speed, material properties, grain size and hardness