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Investigating the effects of hybrid reinforcement particles on the microstructural, mechanical and tribological properties of friction stir processed copper surface composites

Titus Thankachan [a,*], K. Soorya Prakash [b], V. Kavimani [c]

[a] Department of Mechanical Engineering, Karunya Institute of Technology and Sciences, Coimbatore, 641 114, Tamil Nadu, India
[b] Department of Mechanical Engineering, Anna University Regional Campus, Coimbatore, 641 046, Tamil Nadu, India
[c] Department of Mechanical Engineering, Karpagam Academy of Higher Education, Coimbatore, 641 021, India

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ABSTRACT

Friction Stir Processing (FSP) technique was employed in this research to fabricate copper surface composites through incorporating a hybrid mixture of reinforcement particles. Hybrid combination of advanced nitride based ceramic particles (25% AlN + 75% BN) was dispersed onto the surface of copper matrix at varying volume fractions through FSP technique. Results demonstrated an increase in mechanical properties with respect to increase in the amount of particle dispersion. Mechanism of fracture for developed set of surface composites was studied with the aid of fractography. A tremendous increase in wear resistance was observed with respect to increase in hybrid particle dispersion owing to the hardness and self-lubricating characteristics of dispersed ceramic particles.

1. Introduction

Owing to high thermal and electrical characteristics along with enhanced formability and corrosion resistance, copper is considered as one of the most efficient metal in industries [1–3]. But certain limitations such as ductility, low hardness and wear resistance suppress the applications of copper to a large extent [4]. This paved way for the development of copper-based composites, and studies proves that a great number of researches on enhancing the mechanical properties of copper without degrading its electrical and thermal properties has been carried over in recent year. Survey over various researches based on copper composites proves that copper experiences minimal wettability with reinforcement particles [4]. Again to this, introduction of hard ceramic particles into copper matrix seems to affect many bulk properties such a ductility and toughness in a negative manner [5,6]. These disadvantages of ceramic dispersion compelled the researchers to develop surface-based composites based on applications. Studies in regard with the existing surface composites fabrication techniques such as plasma arc spraying, thermal spraying, laser beam, electron beam methods etc has been carried over at large figure in the recent years. Dispersion of ceramic particles onto the matrix surfaces through the above said methods provided a homogenous distribution of particles with minimal agglomerations. But the evolution of high processing temperature leads to the formation of a certain detrimental phases on matrix metal and also increases the chances of matrix-reinforcement reactions [7,8]. So as to avoid the formation of these phases, a processing technique which works under melting point of substrate metal has to be developed which paved way to the consideration of Friction Stir Processing (FSP) technique [9].

Friction stir processing was invented based on the working principle of a solid-state welding technique known as Friction Stir Welding (FSW), wherein a rotating non-consumable tool with a pin and a shoulder travels through the weld seam joining two metals [10,11]. Similarly, in FSP a specifically designed non-consumable rotating tool passes through the metal creating friction and thereby increasing the substrate temperature. Tool pin stirs the molten metal leading to radical plastic deformation resulting in the formation of refined microstructure [12–14]. FSP was first developed for microstructural improvement and for eliminating defects from the casted specimens so as to increase the mechanical properties of the same. But studies have proved FSP as a promising processing technique for developing surface composites [15,16]. A prominent method to enhance the properties of surface composites is to attain ultrafine grain structure for the substrate metal and FSP is an eminent method to refine the microstructure for any metal.

* Corresponding author.
E-mail address: titusmech007@gmail.com (T. Thankachan).

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