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Investigation of microstructure, hardness and wear properties of Al–4.5 wt.% Cu–TiC nanocomposites produced by mechanical milling

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ABSTRACT

The present work deals with studies on the manufacturing and investigation of mechanical and wear behavior of aluminum alloy matrix composites (AAMCs), produced using powder metallurgy technique of ball milled mixing in a high energy attritor and using a blend–press–sinter methodology. Matrix of pre-mechanical alloyed Al–4.5 wt.% Cu was used to which different fractions of nano and micron size TiC reinforcing particles (ranging from 0 to 10 wt.%) were added. The powders were mixed using a planetary ball mill. Consolidation was conducted by uniaxial pressing at 650 MPa. Sintering procedure was done at 400 °C for 90 min. The results indicated that as TiC particle size is reduced to nanometre scale and the TiC content is increased up to optimum levels, the hardness and wear resistance of the composite increase significantly, whereas relative density, grain size and distribution homogeneity decrease. Using micron size reinforcing particulates from 5% to 10 wt.%, results in a significant hardness reduction of the composite from 174 to 98 HVN. Microstructural characterization of the as-pressed samples revealed reasonably uniform distribution of TiC reinforcing particulates and presence of minimal porosity. The wear test disclosed that the wear resistance of all specimens increases with the addition of nano and micron size TiC particles (up to 5 wt.%). Scanning electron microscopic observation of the worn surfaces was conducted and the dominant wear mechanism was recognized as abrasive wear accompanied by some delamination wear mechanism.

1. Introduction

Aluminum-based alloys are widely used as aerospace and automotive components, because of their high specific strength, stiffness and formability. However, both pure Al and Al alloys possess poor wear resistance. On the other hand, Al alloy matrix composites are known to offer better wear resistance and bulk mechanical properties. These composites are synthesized by liquid or powder metallurgy routes. The wear performance of these composites is a subject of strong interest, especially for their potential application in automobile components including cylinder block, piston and brake disks [1]. The wear test is usually conducted under sliding wear conditions using pin-on-disk or block-on-ring tests. Though high volume fractions of hard reinforcements are favored for wear resistance, the wear rate of the counter-body is found to be greatly enhanced by the abrasive action of the reinforcements [2]. Carbides, oxides, nitrides and different intermetallics compounds have been used extensively as reinforcing particulates for AMCs [3]. In specific, SiC and Al_2O_3 were the commonly used ceramic reinforcements and recently NiAl, Ni_3Al and intermetallics composite have been shown to improve the wear resistance of aluminum and magnesium alloys to a level similar to that of SiC reinforced composite, whilst reducing counterface wear rates [4–6]. TiC was not investigated enough as a ceramic reinforcement to Al alloy matrix nanocomposites, however it has been receiving much attention lately for its high melting temperature (3160 °C), low thermal coefficient of expansion, extraordinary hardness, excellent wear and abrasion resistance [7,8]. A decrease of the reinforcement particle size from micrometric to nanometric scale, brings a superior increase in mechanical strength of the composite, but the tendency of particle clustering and agglomeration also increases [9–11]. It is important to note that a homogeneous distribution of the reinforcing particles is essential for achieving the improved properties [12]. Mechanical alloying (M/A) via ball milling has been successfully employed to improve particle distribution throughout the matrix [13–15].

Mechanical alloying is solid-state synthesis process that consists of repeated cold-welding, fracturing, dynamic recrystallization and mechanically activated inter diffusion among the powder particles. A high energy ball mill offers indeed supplementary degrees of freedom in the choice of possible routes for synthesizing

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