Materials and Design 32 (2011) 2157–2164

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Effects of particulate reinforcement and heat treatment on the hardness and wear properties of AA 2024-$MoSi_2$ nanocomposites

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ARTICLE INFO

Article history:
Received 29 June 2010
Accepted 15 November 2010
Available online 20 November 2010

Keywords:
A. Nanomaterials
C. Mechanical alloying
E. Wear

ABSTRACT

In this study, nanocomposites of AA 2024 aluminum alloy matrix reinforced with different volume fractions of nanometric $MoSi_2$ intermetallic particles ranging from 0 to 5%, were produced using mechanical alloying technique. For comparison, samples without reinforcing particles and mechanical alloying and a sample with micrometric $MoSi_2$ particles were also synthesized. The prepared composite powders were consolidated by cold and hot pressing and then heat treated to solution and aged condition (T6). The effects of $MoSi_2$ particle size, volume fraction and also heat treatment on the hardness and wear properties of the composites were investigated using Brinell hardness and pin-on-disc wear tests. The results indicated that although T6 heat treatment increases the hardness of all samples compared to as hot-pressed (HP) condition, the age-hardenability (aging induced hardness improvement) decreases after mechanical alloying and with increasing $MoSi_2$ volume fraction due to the high dislocation density produced during mechanical alloying. With increasing the volume fraction of nano-sized $MoSi_2$ particles up to 3–4%, the hardness of the composites continuously increases and then declines most probably due to the particle agglomeration. The wear sliding test disclosed that the wear resistance of all specimens in T6 condition is higher than that of HP condition and increases with increasing $MoSi_2$ content. Scanning electron microscopic observation of the worn surfaces was conducted and the dominant wear mechanism was recognized as abrasive wear accompanied by some adhesive wear mechanism.

1. Introduction

Aluminum matrix composites (AMCs) are under attention for many applications in automobile, aerospace and military industries because of high strength/weight ratio, high specific modulus, low coefficient of thermal expansion, good wear resistance and also, they can have good electrical and thermal conductivity [1].

Extensive works have been carried out on AMCs to improve their mechanical and tribological properties because of the potential for weight saving and service life increasing in many applications [2]. Different ceramic or intermetallic particles have been used as reinforcing materials such as Al_2O_3 [3], SiC [4], Ni_3Al [5], B_4C [6] and Si_3Ni [7].

An additional drawback of AMCs with ceramic reinforcing is the tendency of ceramic to act as a second-body abrasive against the counterface and thus reduce the overall wear resistance of the tribo-system [2,8]. During the last few years, intermetallics have emerged as a possible substitute for ceramic reinforcements, mainly due to the lower abrasiveness which would lead to a longer service life of tribo-systems [9]. Intermetallics such as NiAl, Ni_3Al and $MoSi_2$ have been shown to improve the wear resistance of aluminum alloys to a level similar to that of SiC reinforced composite, whilst reducing counterface wear rates [2,10,11]. Among these intermetallics, $MoSi_2$ is a novel reinforcement for AMCs due to its high wear properties, high modulus and high thermal stability on the composites [12], which has been only partially studied [9,11–13]. This intermetallic is an excellent candidate to be used as reinforcement in AMCs.

During the past decade, there have been some investigations on the effect of aging treatment on mechanical properties of the AMCs which their matrixes are heat treatable aluminum alloys [12,14–16] and according to some of the results it is possible to improve the mechanical properties of such AMCs with aging.

The size of particulate reinforcements in AMCs generally ranges from a few micrometers to several hundred micrometers [17]. A decrease of the reinforcement particle size from micrometric to nanometric scale, brings a superior increase in the mechanical strength of the composite, but the tendency of particle clustering and agglomeration also increases [18]. It is important to note that a homogeneous distribution of the reinforcing particles is essential for achieving the improved properties [19].

Mechanical alloying via ball milling has been successfully employed to improve particle distribution throughout the matrix. In this process, fracturing and cold welding of the powder particles

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doi:10.1016/j.matdes.2010.11.037