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Processing and surface properties of Al–AlN composites produced from nanostructured milled powders

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ABSTRACT

Al–AlN nanostructured composites were fabricated via the powder metallurgy method using mechanically milled aluminum powder mixed in a planetary ball-mill with different content of AlN (0, 2.5, 5, 10 wt.%) as the reinforcement. After milling for 25 h, powders were degassed and die-pressed uniaxially in a steel die and then sintered at 650 °C for different times. The sinterability, tribological and corrosion behavior of composites were investigated at predefined conditions. Sinterability of composites was degraded with increasing the reinforcement content. Wear resistance was improved by increasing volume fraction of AlN and this improvement was more pronounced at higher fraction of reinforcement. The potentiodynamic polarization was used for corrosion testing in 0.05 and 0.5 mol/L NaCl solutions. According to the results of the experiment, the amount of the second phase did not exhibit any detectable influence on the corrosion current density. In the diluted solution, E_{pit} was reduced in the diluted solution as a result of decrease in the amount of reinforcing particles. In the concentrated solution, E_{pit} was equal or lower than E_{corr} for all the specimens. The SEM observations revealed that regular cracks were distributed all over the surface and corrosion products had covered the surface.

1. Introduction

Aluminum matrix composites (AMCs) have attracted much attention in automotive, aerospace and military industries, due to their high mechanical and physical behavior [1,2]. AMCs usually are reinforced with SiC [3] and/or Al_2O_3 [4]. In order to improve the properties such as wear resistance, researchers have examined other reinforcing materials such as carbide [5] and nitride ceramics [6]. Aluminum nitride (AlN) is a good example with appropriate physico-chemical, mechanical and thermal properties which suggest it as a suitable reinforcement material for aluminum [7]. AlN can hardly react with molten Al and exhibits high thermal conductivity (320 W m^{-1} K^{-1}), low dielectric constant (8.8 at 1 MHz), high wear resistance, low density [8] and low coefficient of thermal expansion ($\approx 4.7 \times 10^{-6}$ K^{-1}), which is closed to that of silicon [8]. AlN particulates demonstrate high electrical resistivity (10^{13} Ω cm) by which the galvanic corrosion follows a reducing trend and they, additionally, hydrolyze easily especially in an alkaline environment [8,9].

Among many techniques applied for fabrication of aluminum based composite materials, consolidation of milled powders by cold compaction and sintering could be of interest for production of large batches of small parts [10]. Composite powder could be obtained by milling of Al/AlN mixture with predefined ratio [7] or reaction ball-milling of Al powder under nitrogen atmosphere. The latter can be performed by 'gas/solid reaction milling' of elemental Al powder, i.e. attrition milling in the presence of urea [11,12] or 'cryomilling' of Al, i.e. mechanical alloying in liquid nitrogen [13–15]. However, although few reports [16,17] are available in the literature focusing on the sintering process of mechanically milled aluminum matrix composite powders, some studies [18–21] have been performed on tribological and corrosion behavior of Al/AlN composites.

One of the main obstacles in the use of aluminum alloy-based composites is the influence of reinforcement on corrosion resistance, where a protective oxide film imparts corrosion resistance. The addition of a reinforcing phase can increase the frequency of discontinuities on the film, thereby increasing the number of sites where corrosion can be initiated and rendering the composite liable to severe attacks [18,20,21].

Some researchers proposed that introduction of reinforcing material results in the preferential attack at the reinforcement/aluminum matrix interface. Other studies [22,23], believed that the galvanic corrosion could be restricted when a non-conductive reinforcement is examined. Researchers [24] also supposed that galvanic corrosion

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