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Wear Response of A356-doped Ce for Potential Application in Vehicle Components

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The aluminum alloys exhibit interesting combination of properties such as light weight, ductility, and corrosion resistance, as well as high electrical and thermal conductivity. Thus, they have been widely used in the automotive, aeronautical, aerospace and military applications such as in the fabrication of frame and body parts of commercial and military aircraft and vehicles, in which effective formability and high specific resistance are needed. Nevertheless, the aluminum alloys have low hardness, resulting in poor wear resistance. Wear being one of the most common phenomena in engineering practices, the friction and abrasion mechanisms reduce the lifetime of aircraft and vehicles parts exposed to different mechanical actions [1]. Therefore, the academic and scientific research in materials science plays a vital role in ensuring the development of engineering materials with improved mechanical performance. In this regard, the A356 aluminum alloy is one of the most widely used lightweight materials in the aircraft and automotive components due to its good castability, relative high mechanical strength and responsive to heat treatments. The mechanical properties of A356 alloy depend on different factors such as chemical composition, microstructure and heat treatments. The mechanical performance of this aluminum alloy can be enhanced by the fabrication of metal matrix composites by the addition of hard particles. Rare earths have been promising elements to reinforce aluminum alloys [2]. The aim of this work was to study the wear behavior of an A356 aluminum matrix reinforced with Ce additions using an Al-Ce master alloy.

Three different composite samples were studied: A356 aluminum alloy with 0, 0.3 and 0.5 wt.% Ce. The addition of cerium was in the form of Aluminum-Cerium (Al-10%Ce) master alloy, that was prepared by mechanical milling in a high energy mill (SPEX 8000M) during 10 h under vacuum. The master alloy powders were compacted at room temperature and 400 MPa into a cylindrical shape (10 mm diameter). The composite specimens were prepared by casting process. The required amount of master alloy was weighed out and poured in the crucible when A356 alloy became molten (750 °C). Al-Ti-B was used as grain refining. Degassing process was carried out by use of Ar inert gas. The as-cast specimens were machined into flat specimens in the form of circles of 2 inch diameter, ¼ inch high, and a ¼ inch diameter concentric hole. The samples were grinded by silicon carbide (SiC) papers and then polished with 1 μm alumina solution. Then the samples were solubilized at 500 °C for 5 h, and aged at 180 °C for 10 h. Hardness and wear resistance evaluation were conducted in order to determine the suitability of Ce as a particle reinforcement of an A356 aluminum matrix. The abrasion test was performed using a Taber Abrasion Tester Model 5150. A load of 500 grams per arm was applied during 1500 cycles, the test was operated at a fixed speed of ~ 1.23 cycles per second. The hardness on the cross-section polished specimens was measured by the Vickers microhardness method (LM 300AT Leco

MicroHardness Tester). Scanning electron microscopy (SEM) analyzes were used to characterize the worn surfaces (JSM-5800LV). Wear particles were analyzed by energy dispersive spectroscopy (EDS) to determine the chemical composition and to understand the wear mechanism.

The alloy with 0.5 wt.% Ce had an increase of 7% in hardness compared to the unreinforced A356 alloy, in both, as-cast and aged conditions. The addition of 0.5% wt. Ce to A356 alloy caused reduction of Taber wear index of 27%. The three-dimensional views of the worn surface taken through SEM observations (Fig. 1) showed significant differences in the depth of wear debris. The detachment of particles is greater in the unreinforced alloy. Although no detachment of cerium particles was detected (Fig. 2), they are not homogeneously distributed throughout the matrix. Variations in the synthesis process and in the cerium amount should be investigated to determine further improvement of wear resistance in the A356 alloy.

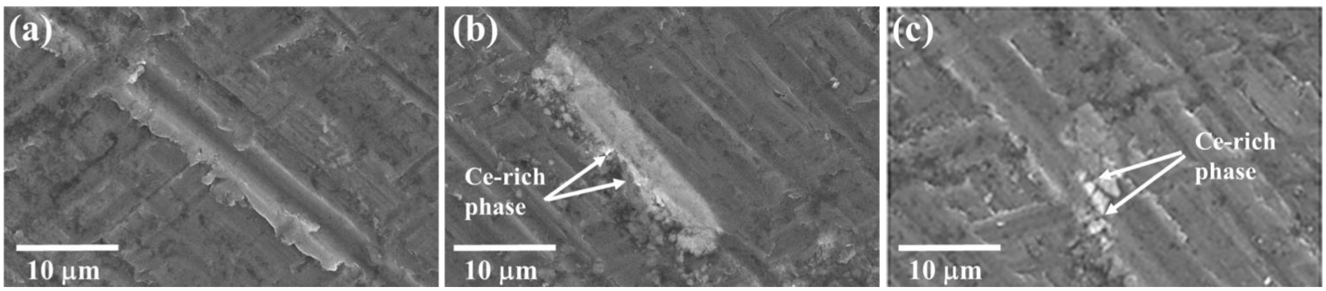

Figure 1. SEM micrographs of wear debris of A356 with: a) 0, b) 0.3 and c) 0.5 wt.% Ce.

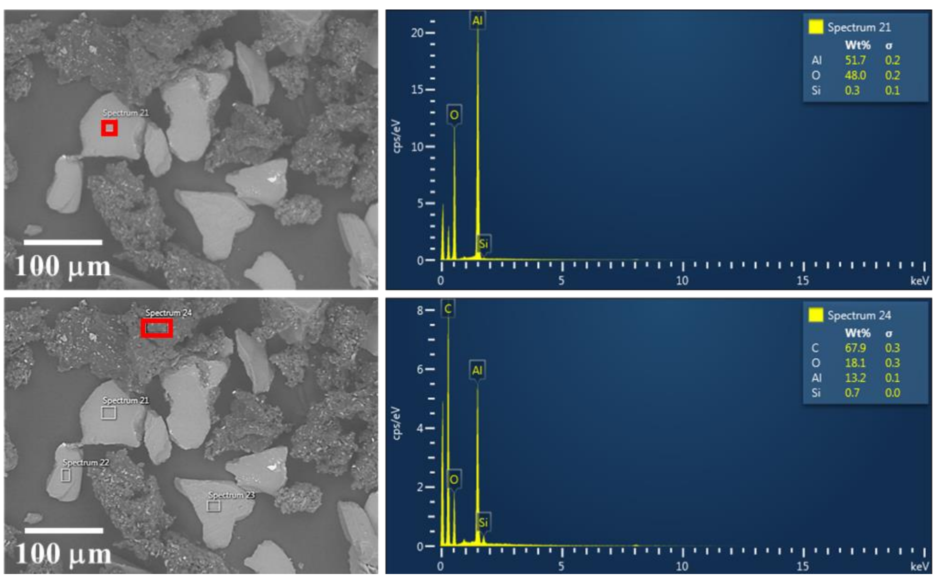

Figure 2. SEM micrographs and EDS results of wear particles of A356-0.5 wt.% Ce composite.

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