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Interface analysis and wear behavior of Ni particulate reinforced aluminum–silicon composites produced by PM

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ABSTRACT

This study is concerned with the influence of Nickel, as reinforcement, in an aluminum–silicon (AlSi) alloy when regarding wear behavior. For these composites, the effect of Ni content, in the tribopair performance, was evaluated. For this purpose, the pin but also the counterface wear behavior was analyzed.

Nickel particulate reinforced aluminum–silicon (AlSi) composites, with 5, 12.5 and 20 wt.% Ni were produced by a hot-pressing route. Microstructural characterization showed a uniform distribution of the Ni particulates in the AlSi matrix. EDS and XRD analyses revealed that the particle/matrix interface was formed by Al_3Ni intermetallic. Reciprocating pin-on-plate wear tests were performed with AlSi and AlSi–Ni pins against a gray cast iron (GCI) counterface. It was observed that the wear behavior of the AlSi–Ni/GCI tribopair is improved when compared with the AlSi/GCI system.

1. Introduction

Several aluminum-metal matrix composites (AMCs) have been developed for tribological applications (e.g. automotive components such as engine pistons, where wear properties are crucial) [1–3]. Most of the existing research is focused on AMCs reinforced with ceramics, mostly SiC and Al_2O_3 [2,4].

It has been reported that the wear behavior of metal matrix composites is influenced by several factors [4–9]. Wang and co-workers [5] studied the wear behavior of an aluminum alloy (Al6092) reinforced by 15 vol.% Ni_3Al. They reported that the composite presented a superior wear resistance compared to the Al6092 monolith. The improvement in wear behavior was based on the fracture toughness of the reinforcement [5]. It is known that ceramic reinforcements can be detached or fragmented during the sliding which may result in a worst wear behavior due to the third-body effect [4,5,7]. The third-body effect was attributed to the poor bonding between the metal matrix and the ceramic, once no interface is formed. The process of crack nucleation between reinforcement and matrix during sliding leads to fragmentation and delamination of the surface [4,5,7]. Kumar and co-authors [8] in a study about the effect of particle size on operative wear mechanism in particle reinforced aluminum alloy composites at elevated temperatures mentioned that an effective interface allows achieving better mechanical and tribological properties, since load transfer can occur through the interface. Also, Das and co-authors [9] reported an increase of hardness if there is a smother interface between the matrix and reinforcement.

Intermetallics are promising materials to act as reinforcements in aluminum alloys, especially those from the Ni–Al system [2] due to their high hardness and strength [10,11]. There are some studies focusing on aluminum alloys reinforced with Ni_3Al and NiAl [2,5,12] and also with Al_3Ni [12,13]. In some of these studies the intermetallics are added to the matrix as raw materials [2,5], while in other studies only Nickel is added to the matrix and there is an in-situ formation of the intermetallics during processing [12,13]. This last approach is preferred once the in-situ formation of reinforcing particles seems to enhance the wear performance of composite materials [14]. By using this method intermetallics arise in the reaction zone between particle and matrix (interface) which leads to a continuous bond between reinforcement and matrix, inexistent in ceramic reinforced metal matrix composites. The existence of this interface is beneficial to the tribological behavior of these composites [2,5]. Nevertheless, the characterization of the formed interface (regarding chemical composition, hardness and wear behavior) is mandatory to conclude about the role of these in-situ formed compounds in the composite.

This work is concerned with the dry sliding behavior of three Ni-reinforced AlSi composites (AlSi-5wt.%Ni; AlSi-12.5wt.%Ni and AlSi-20wt.% Ni) against a GCI counterface. For comparison purposes unreinforced Al-Si specimens were tested under the same

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Table 1
Chemical composition of AlSi alloy (according to manufacturer).

Element	Al	Si	Fe	Cu
wt.%	88.352	11.5	0.145	0.003

conditions. The controlling wear mechanisms were investigated, and besides the pin also the counterface wear behavior was also studied.

2. Experimental details

2.1. Fabrication of AlSi–Ni composites

Nickel particle-reinforced aluminum–silicon composites were produced from Aluminum–Silicon (AlSi) spherical powder, with maximum particle diameter of 45 μm and Nickel powder (99.8 wt.% Ni), with maximum particle diameter of 45 μm.

The chemical composition of the AlSi alloy is listed in Table 1.

Both materials were purchased from TLS Technik. Scanning electron microscopy (SEM) images of AlSi and Ni powders are presented in Figs. 1(a and b). Fig. 2 shows AlSi and Ni powders size distribution (according to manufacturer), showing that 90% of the AlSi powders have a diameter below 46.31 μm, while for Ni powders this value is 36.46 μm.

AlSi powder and Ni particles were mechanically mixed in a blender for 20 min. The obtained mixture was divided and placed inside graphite moulds, with 8 mm width and 43 mm length. AlSi–Ni samples were then sintered by means of pressure-assisted sintering process, in vacuum (10^{-2} mBar), using a high frequency induction furnace (Fig. 3), according to the following procedure. The mould was placed inside the chamber, where the sample was compressed at 1 MPa, and then heated up to 500 °C, with a heating rate of 25 °C/min. When the temperature reached 500 °C the pressure on the sample was raised to 35 MPa (while the heating proceeds at 25 °C/min till 550 °C). The sample was maintained at 550 °C with 35 MPa pressure, for 15 min. Afterwards the samples were allowed to cool inside the mould, in vacuum, till room

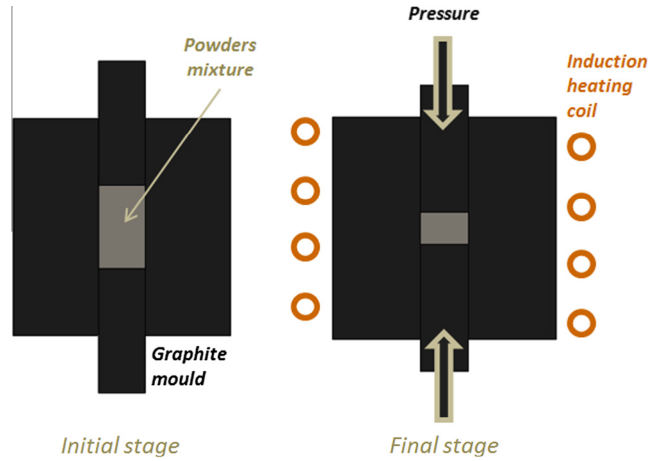

Fig. 3. Schematic representation of the hot-pressing sintering system.

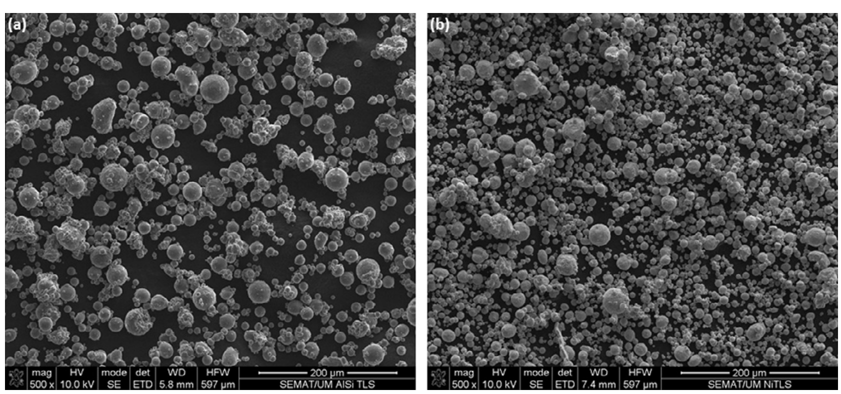

Fig. 1. SEM images of (a) AlSi and (b) Ni powders.

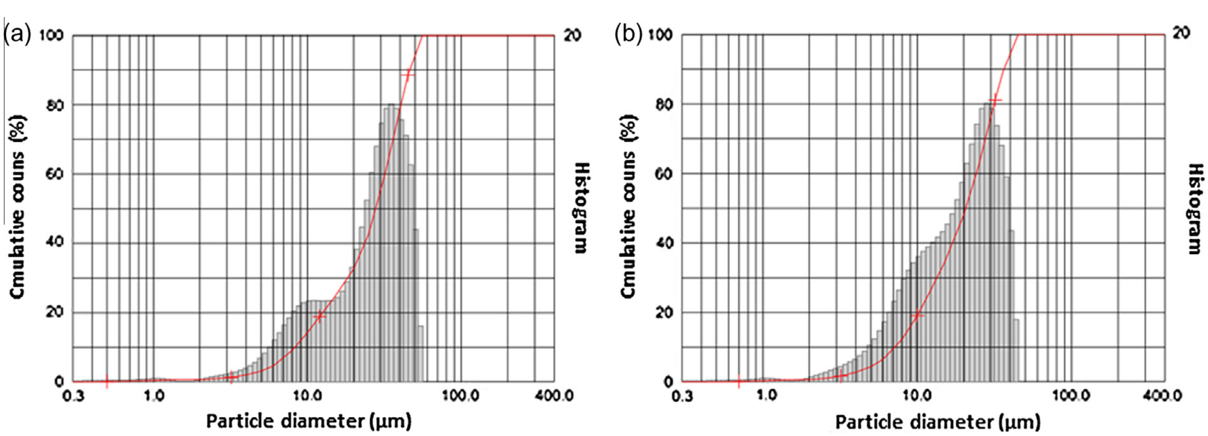

Fig. 2. (a) AlSi and (b) Ni powders size distribution (according to the manufacturer).