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Wear Resistance in Dry and Lubricated Conditions of Hard-anodized EN AW-4006 Aluminum Alloy

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Abstract : Aluminum alloys are widely used in many engineering applications due to their advantages such ashigh electrical and thermal conductivities, low density, high strength to weight ratio, and good corrosion resistance. However, their low hardness and poor tribological properties still limit their use in industrial fields requiring sliding contacts. Hard anodizing is one of the most common solution for overcoming issues concerning the insufficient friction resistance of aluminum alloys. In this work, the tribological behavior ofhard-anodized AW-4006 aluminum alloys in dry and lubricated conditions was evaluated. Three different hard-anodizing treatments were selected: a conventional one (HA) and two innovative golden hard-anodizing treatments (named G and GP, respectively), which involve the sealing of the porosity of anodic aluminum oxides (AAO) with silver ions at different temperatures. Before wear tests, all AAO layers were characterized by scanning electron microscopy (VPSEM/EDS), X-ray diffractometry, roughness (Ra and Rz), microhardness (HV0.01), nanoindentation, and scratch tests. Wear tests were carried out according to the ASTM G99-17 standard using a ball-on-disc tribometer. The tests were performed in triplicate under a 2 Hz constant frequency oscillatory motion, a maximum linear speed of 0.1 m/s, normal loads of 5, 10, and 15 N, and a sliding distance of 200 m. A 100Cr6 steel ball10 mm in diameter was used as counterpart material. All tests were conducted at room temperature, in dry and lubricated conditions. Considering the more recent regulations about the environmental hazard, four bio-lubricants were considered after assessing their chemical composition (in terms of Unsaturation Number, UN) and viscosity: olive, peanut, sunflower, and soybean oils. The friction coefficient was provided by the equipment. The wear rate of anodized surfaces was evaluated by measuring the cross-section area of the wear track with a non-contact 3D profilometer. Each area value, obtained as an average of four measurements of cross-section areas along the track, was used to determine the wear volume. The worn surfaces were analyzed by VPSEM/EDS. Finally, in agreement with DoE methodology, a statistical analysis was carried out to identify the most influencing factors on the friction coefficients and wear rates. In all conditions, results show that the friction coefficient increased with raising the normal load. Considering the wear tests in dry sliding conditions, irrespective of the type of anodizing treatments, metal transfer between the mating materials was observed over the anodic aluminum oxides. During sliding at higher loads, the detachment of the metallic film also caused the delamination of some regions of the wear track. For the wear tests in lubricated conditions, the natural oils with high percentages of oleic acid (i.e., olive and peanut oils) maintained high friction coefficients and low wear rates. Irrespective of the type of oil, smallmicrocraks were visible over the AAO layers. Based on the statistical analysis, the type of anodizing treatment and magnitude of applied load were the main factors of influence on the friction coefficient and wear rate values. Nevertheless, an interaction between bio-lubricants and load magnitude could occur during the tests.

Keywords : hard anodizing treatment, silver ions, bio-lubricants, sliding wear, statistical analysis
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