Rare Metal Materials and Engineering
Volume 45, Issue 5, May 2016
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: Rare Metal Materials and Engineering, 2016, 45(5): 1122-1127.

ARTICLE

Friction and Wear Performances of 7475 Aluminium Alloy after Anodic Oxidation

Kong Dejun,   Wang Jinchun,   Liu Hao

Jiangsu Key Laboratory of Materials Surface Science and Technology, Changzhou University, Changzhou 213164, China

Abstract: A layer of oxide film was prepared on the surface of 7475 aluminum alloy by anodic oxidation. The friction and wear performance of the film at different loads were investigated with the friction and wear tests. The atomic binding energy spectrum, the wear morphologies, the surface hardness and the residual stress were analyzed with XPS, SEM, hard meter and XRD stress tester, respectively. The results show that the oxide film on the surface is relatively dense after anodic oxidation, existing in the form of Al_2O_3, and diffusion type bonding is contained at the interface. The average friction coefficient is decreased after anodic oxidation, indicating that the friction performance is improved. The wear mechanism of the original sample is adhesive wear and tear, accompanied with abrasive wear, and the wear mechanism of the sample after the anodic oxidation is abrasive wear, where high surface hardness is the main factor of the wear resistance.

Key words: anodic oxide film; surface morphology; friction coefficient; wear performance

Because of high specific strength, corrosion resistance, easily machining and other excellent performances, aluminum alloy has been widely used in aerospace industry [1,2]. However, as friction material, aluminum alloy has high friction coefficient and wear volume, and it is easy to strain and difficult to lubrication [3]. 7475 aluminum alloy is a new aluminum alloy of Al-Zn-Mg-Cu that is strengthened with heat treatment, but it inevitably possesses some shortcomings of aluminum alloy. In order to improve the performances of aluminum alloy, the existing surface modification methods mainly include laser cladding, chemical plating Ni-P coating, micro arc oxidation, sol-gel method and etc. [4-9] Anodic oxidation is referred to that in an appropriate electrolyte with metals as the anode, the dense oxide film is formed in the sample surface [10] under the effect of impressed current. The typical anodic oxidation is sulfuric acid anodizing in which the sulfuric acid is used as the electrolyte and aluminum workpiece as anode, lead or aluminum as cathode. Al_2O_3 film prepared in the surface of aluminum alloy can improve its strong adhesion and surface hardness; as a result, the purpose of enhancing wear resistance can be achieved [11]. In the present investigation, the method of sulfuric acid anodizing was used to generate a layer of dense anodic oxide film in the surface of 7475 aluminum alloy, energy spectrum of oxidation film was analyzed with XPS, and the wear properties and friction coefficients were inspected, and the effects of surface hardness and residual stress on properties of the friction and wear were analyzed.

1 Experiment

The tested material was 7475 aluminum alloy with chemical compositions as follows (wt%): Si≤0.10, Fe≤0.12, Mn≤0.06, Cu 1.2~1.9, Mg 1.9~2.6, Cr 0.18~0.25, Ti≤0.06, Zn 5.2~6.2, Al balance. Anodic oxidation process included degreasing → removing the natural oxide film → chemical polishing → washing → heat sealing. The technological parameters were as follows: concentration of sulfuric acid was 180 ± 2 g/L, aluminum ion concentration 5~10 g/L, the rest was water, temperature 20 ± 0.5 °C, the current density 1.5 ± 0.1 A/dm^2. The stirring the method was used with compressed air, time was 45 min, and the required samples were finished. The wear test was conducted on HRS-2M type reciprocating

Received date: May 19, 2015
Foundation item: the Science and Technology Support Project of Jiangsu Province, China (BE2012066)
Corresponding author: Kong Dejun, Ph. D., Professor, College of Mechanical Engineering, Changzhou University, Changzhou 213164, P. R. China, Tel: 0086-519-81169810, E-mail: kong-dejun@163.com

friction and wear tester, friction method included reciprocating, friction pair *Φ*5 mm ceramic ball, respective loads (600, 800, 1000 g), reciprocating times (500 times/min), reciprocating length (5 mm). Friction coefficients were recorded automatically by the test software. Via testing friction coefficients before and after anodic oxidation and varying the applied load, the effect of load on friction coefficient was investigated. The worn morphologies and chemical elements before and after anode oxidation were analyzed by JSM-6360LA type SEM and EDS, respectively. Residual stresses were measured adopting roll fixed method, with Cr target Kα radiation, crystal of (311), starting and ending angle was 145°, 135°, scanning step of 0.10°, counting time of 0.50 s.

2 Results and Discussion

2.1 Surface morphology and XPS analysis

After anodic oxidation, the sample surface was covered with a dense Al_2O_3 oxide film, as shown in Fig.1a. There are some black spots on the surface after anodic oxidation, which are caused by enrichment phenomenon of Si and other insoluble materials, affecting the appearance quality of aluminum alloy. The essence of anodic oxidation is the electrolysis of water and the hydrolysis of the electrolyte which occurs under the function of current after energization. Hydrogen gas is generated at the cathode, and negatively charged anions move toward the anode, emitting electrons to produce oxygen. The parts of the oxygen react with anodic aluminum and the alumina membrane is generated. Fig.1b is the interface morphology of anodic oxide film. The diffusion at the interface is obvious to form a narrow white band where a mutual diffusion occurs, i. e. the Al atoms of the base metal diffuse into the oxide film and O atoms in the oxide film move to the base mental, which suggests that the interface of oxide film-substrate is diffusion combination.

As shown in Fig.2a, the peak of Al 2p at binding energy of 74.37 eV represents the form of Al^{3+}, corresponding to Al in Al_2O_3. The peak of O 1s at binding energy of 531.82 eV represents the form of O^{2+}, as shown in Fig.2b, corresponding to O in Al_2O_3. With the oxidation going on, the dense oxide film presents atoms O from diffusing and slows down the oxidation of the oxide film and the base metal. As shown in Fig.2c, the C 1s peak is located at 284.79 eV, which is presented in the form of C^{4+} combined with O to form C-O and C-H bonds.

2.2 Friction coefficients

Fig.3 shows the friction coefficients-wear time curve under different loading conditions. The wear process can be divided into a fast rise stage, a fluctuation stage and a stability stage [12]. (1) The fast rise stage: the friction coefficient increases rapidly in this stage, which is due to the asperity on surface and uneven surface. (2) The fluctuation stage: friction coefficient fluctuates in a certain range and it is unstable, which is mainly because of the friction surface after the first stage. The friction coefficient is high, and with the continuous wear, a lot of friction heat is generated. (3) The stability stage: the friction coefficient tends

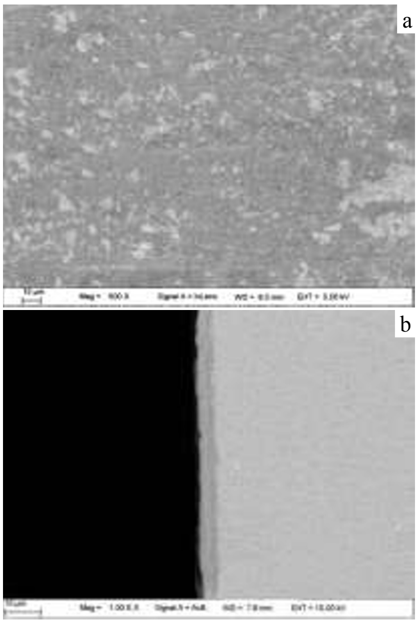

Fig.1 Surface (a) and interface (b) morphologies of anodic oxide film

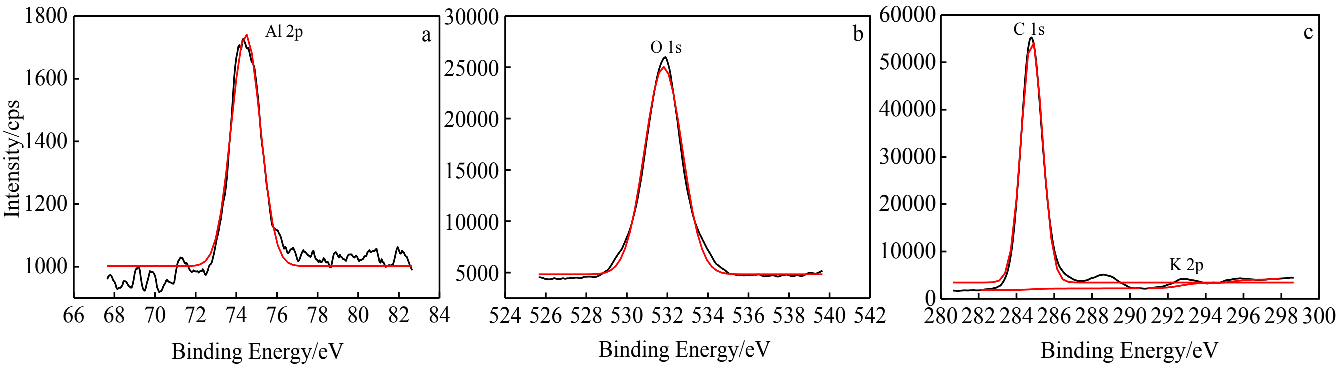

Fig.2 XPS spectra of chemical elements on the anodic oxide film: (a) Al, (b) O, and (c) C