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Cavitation erosion resistance of microarc oxidation coating on aluminium alloy

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ABSTRACT

Two ceramic coatings are prepared on 2124 aluminum alloy by microarc oxidation (MAO) technology. To explore the cavitation erosion resistance of the MAO coating, cavitation tests were performed by using a rotating-disk test rig. The mass losses, surface morphologies, chemical compositions and the phase constituents of the samples after cavitation tests were examined by using digital balance, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD), respectively. The results indicate that the MAO coatings can extend the incubation period of aluminum alloy, and thus enhance the cavitation erosion resistance as compared to the untreated aluminum alloy samples. After duration of 63 h cavitation test, a lot of erosion pits and the particles in various shapes can be observed on the surfaces of the aluminum alloy samples, while only a few erosion pits are observed on the MAO coatings. Moreover, the mean depths of erosion on the MAO coatings are lower in the first 30 h and are independent on erosion time. The results show that the cavitation erosion of MAO coating is governed by water mechanical impaction, resulting from the effects of brittle fracture of the MAO coating.

1. Introduction

Aluminum alloys has received much attention for engineering applications, such as hydraulic machinery, ship, automobile, aerospace and machine tool spindles, due to their relatively inexpensive cost, low density, high specific strength and stiffness. However, cavitation phenomenon occurs frequently due to local pressure fluctuations in the hydraulic systems, which can cause vibration and noise of the machine, the variation in the flow hydrodynamics, and the most important of all, material cavitation erosion [1]. Therefore, the poor cavitation erosion resistance of the aluminum alloys poses a serious obstacle to their commercial application in the hydraulic systems.

Over the last few decades, considerable efforts have been devoted to address cavitation erosion of the aluminum alloys. Fe–30Mn–10Al alloy [2] and Cul2Mn8A13Fe2Ni Alloy [3] exhibit higher cavitation erosion resistance than that of the traditional materials, including copper alloys, aluminum alloys, and even stainless steels. However, these alloys are still inadequate compared with the advanced ceramic material. In recent, hard material coatings prepared by various surface modifications have been widely applied to protect on metal alloy from the damage of cavitation erosion. For example, 5086-H111 aluminum alloy [4,5], laser surface alloyed coatings [6,7], diamond-like carbon films [8], Al_2O_3–13%TiO_2 coatings [9], etc. have been present. As a result, cavitation erosion resistance of matrix alloy has been significantly enhanced for the intruding of the ceramic coating or the DLC film.

Several coating techniques, including thermal spraying, electroplating, laser surface modification, anodic oxidation and vapor deposition, etc. [10–17], have been found application in the engineering industry. However, it is found by contrast that: coating by thermal spraying [10] is brittle and uneven; electroplated coating [11] is complex in pretreatment, poor in adherence and harmful to the environment; laser cladding coating [12,13] has a brittle fracture, a high manufacturing cost, and a limit on the workpiece size; anodic oxide coating [14,15] has low hardness, weak compactness and thin thickness; diamond-like carbon coating (DLC) [16,17] by the vapor deposition technique is super high in hardness but extremely thin in the coating thickness, to be lower in carrying of a contact load. Therefore, it is necessary to prepare a coating onto aluminum alloy to enhance surface comprehensive performance, so as to resist cavitation erosion and enlarge service life. Microarc oxidation (MAO) [18–20] is a breakthrough for the traditional technique of anodic oxidation in recent. With this method, compact ceramic coatings can be formed on the surface of Al alloys.

In the present study, a aluminum alloy 2124 is selected as manufacturing a water lubricated bearing or water lubricated seal, which is suitable for use in fluid machinery, e.g., pump, turbine, compressor, machine tool spindle, etc. However, cavitation

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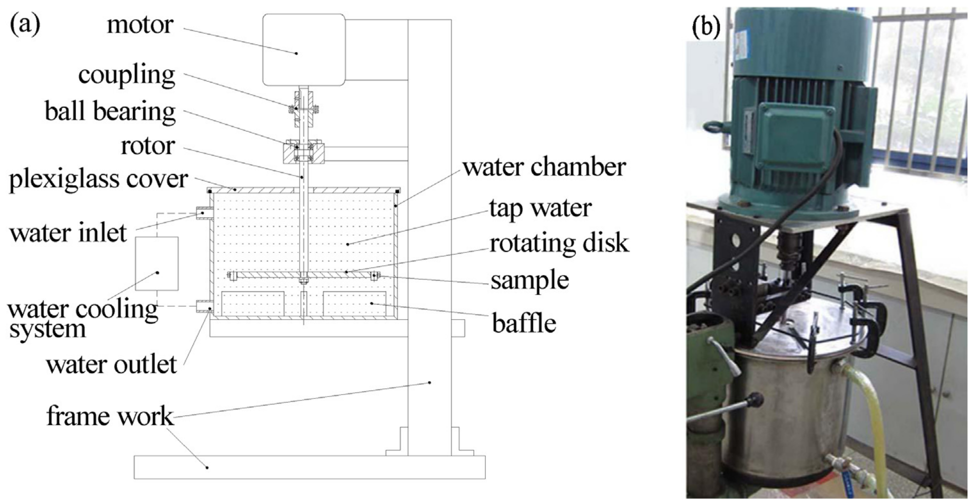

Fig. 1. The self-made rotating disk test rig. (a) Schematic, (b) photo.

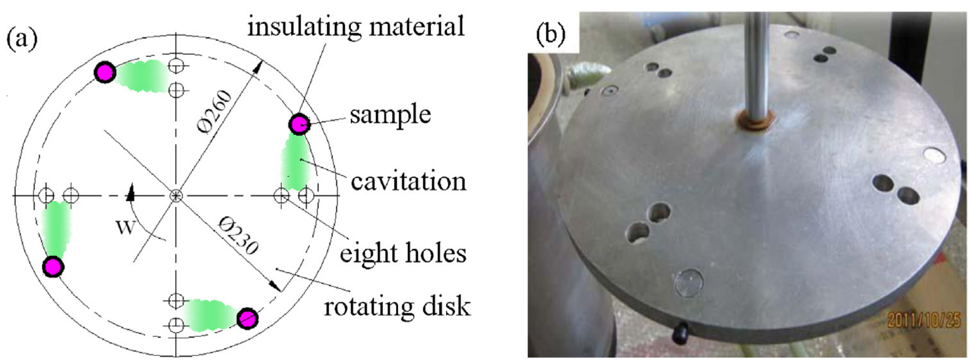

Fig. 2. The rotating disk. (a) Schematic, (b) photo.

erosion is a restraint to aluminum alloy to limit its application in the water lubricated bearing. It is well known that the MAO coatings are composed of an external layer and an internal layer. The external layers are well known to be rough, uneven, and very brittle, so the surface wear resistance of the coatings is quite poor [19]. However, the internal layers of MAO coatings are very hard, corrosion-resistant and wear-resistant, and the research on cavitation erosion resistance of the MAO coating has not yet been reported so far. In view of this, the main aim of the current work is to (a) investigate the cavitation erosion resistance of the MAO coating onto aluminum alloy 2124 by the rotating-disk test rig, and (b) attempt to reveal the cause of these effects by surface analyses.

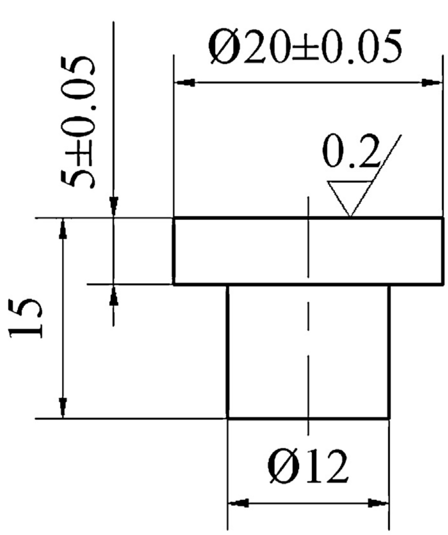

Fig. 3. Dimensions and tolerances of the test sample.

2. Experiment details

2.1. Test rig

The self-made rotating disk test rig, shown in Fig. 1, was developed to generate an aggressive type of cavitation. The test rig mainly consists of a rotating disk, a slender rotor, a motor, a closed tap water chamber, and a water cooling system. The rotating disk is installed on the slender rotor supported by two ball bearings, which is placed in the water and driven by the motor with a rated power of 7.5 kW. The water chamber is covered by a transparent plexiglass plate for the convenient observation of the cavitating flow. To keep the water temperature at around 25 °C, a water cooling system is employed to circulate and cool the water inside the chamber, and inlet and outlet piping are provided by control valves. Six baffles equally spaced are welded at the bottom of the chamber to minimize rotation of tap water and keep bubbles to collapse over the test samples. Fig. 2(a) shows the schematic of the rotating-disk with a diameter of 260 mm. To induce the cavitation, eight holes with a diameter of 12 mm were made on the disk surface, which are in the front of test samples and served as the cavity inducers. To keep dynamic balance, four samples must be all installed on the disk in experiment, or pair of samples is situated