



Corrosion wear synergistic behavior of Hastelloy C276 alloy in artificial seawater



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Abstract: A systematic investigation was carried out to discuss the corrosion and tribocorrosion behaviors of Hastelloy C276 alloy sliding against Al_2O_3 pin in artificial seawater, using a pin-on-disk tribometer integrated with a potentiostat for electrochemical control. The results show that the great decrease of open circuit potential and three orders of magnitude increase of corrosion current density occur caused by friction. There are clearly synergistic effect between corrosion and wear, resulting in corrosion-induced-wear and wear-induced-corrosion in tribocorrosion process. The contribution of pure mechanical wear to total material loss exceeds 70% in all sliding conditions, so mechanical wear is the dominant factor during tribocorrosion. For considering synergistic effect between corrosion and wear, the contribution of wear-induced-corrosion to total material loss is not very high although corrosion rate is greatly accelerated by friction. The fraction of corrosion-induced-wear to the total material loss is high and in the range of 14.6%–20.5% under all sliding conditions.

Key words: tribocorrosion; Hastelloy C276 alloy; synergistic effect; seawater

1 Introduction

In many situations, passive alloys are subjected to combined corrosion and wear, which can be defined as tribocorrosion. These can lead to the destroy or even complete removal of passive film from contact surface, resulting in accelerated metal dissolution, which in turn causes accelerated wear loss [1–4]. Over past few years, investigation on tribocorrosion behaviors of materials subjected to corrosion and wear is a hot topic. Stainless steel and CoCrMo alloy are the most frequently used metals in tribocorrosion field [2,5].

Nickel-based alloys are widely used in chemical industry (vessels, pipes, heat-exchangers and pumps), automotive industries and marine industry (pumps, impellers, valves, and other kinds of equipments). Recently, the tribocorrosion behavior of Ni–Cr alloy was investigated by researchers. The tribocorrosion behavior of overlay welded Ni–Cr 625 alloy in sulfuric and

nitric acids under potentiostatic was investigated by ESPALLARGAS and MISCHLER [6]. The tribocorrosion behavior in sulfuric acid was similar to that of stainless steels found in other studies, with much lower wear at cathodic potential compared with passive conditions. However, wear behavior in nitric acid was highly influenced by the reduction reaction of nitric acid at the electrode–electrolyte interface, which leads to the oxidation of the alloy even at cathodic potential. BI et al [7] studied the tribocorrosion property of Ni–17.5Si–29.3Cr alloy sliding against a Si_3N_4 ball in comparison with AISI 321 stainless steel in 1 mol/L H_2SO_4 solution. The results indicated that the alloy showed excellent corrosion resistance and anti-wear ability compared with AISI 321 stainless steel. However, the fundamental mechanism that determines the wear-corrosion synergism in tribocorrosion of Ni-based alloy in chloride-containing solution has not been fully understood.

The aim of this work is to assess the tribocorrosion

behavior of Ni–Cr alloy (Hastelloy C276) in artificial seawater. The counterpart material is alumina, which is considered to act as an inert antagonist in this experiment. Ceramic materials have excellent insulation, high hardness and good wear resistance, making them suitable for investigating the tribocorrosion properties of metals as counterpart materials. Corrosion wear experiments were carried out in a developed apparatus allowing for well-controlled mechanical and electrochemical conditions.

2 Experimental

2.1 Materials and solutions

The researched metallic alloy in this experiment was Hastelloy C276 nickel-based alloy with the following chemical compositions: 16% Cr, 16% Mo, 5% Fe, 4% W, 2.5% Co, 1% Mn, 0.35% V, 0.08% Si, 0.01% C, balance Ni. The alloy was machined into a ring with an outer diameter of 54 mm and an inner diameter of 38 mm. And only upper surface of the alloy was in touch with seawater and other surfaces were covered with paint for insulation to avoid electrochemical test confusion. The Al_2O_3 pin with a flat surface at one end of a cylinder (diameter: 4.7 mm, height: 13 mm) was used as counterpart material. All samples were polished down to mirror quality using 220, 500 and 1000 grade grit paper and with 1 μm diamond suspension, respectively. Corrosive solution was artificial seawater prepared according to ASTM D1141–98 standard. The pH value was 8.2. All tests were carried out at room temperature (20–25 $^{\circ}\text{C}$).

2.2 Wear measurements

Corrosion wear test setup combined with in-situ electrochemical measurements was illustrated in our previous paper. Sliding tests were carried out using an MMW–1 pin-on-disk tribometer. In-situ electrochemical measurements during sliding were fulfilled using CHI760C potentiostat. Wear track was a ring with a mean diameter of 46 mm and a width of 4.7 mm. The area of wear track was about 6.8 cm^2 . The rotation speed in this experiment was 100–400 r/min with linear velocity of 0.27–1.08 m/s and normal load was 100–200 N. After corrosion-wear tests, the metallic specimens were ultrasonically cleaned in acetone to remove debris. Gravimetric measurement before and after tribocorrosion were finished. The volume loss can be calculated as

$$V = \frac{m_0 - m_1}{\rho} \quad (1)$$

where V is the volume loss (mm^3), m_0 is the mass of material before wear (mg), m_1 is the mass of material after wear (mg), and ρ is density of the alloy. The specific wear rate, k , can be determined as

$$V = kLN \quad (2)$$

where N is the applied load and L is the total sliding distance. The morphologies of worn surfaces were examined using JEM–5600LV scanning electron microscope (SEM). All tests were repeated at least three times for reproducibility.

2.3 Electrochemical measurements

Electrochemical measurements were concluded using a CHI760C potentiostat with three-electrode test system. Metallic specimen was prepared as working electrode (WE). A saturated calomel electrode (SCE) close to working electrode served as reference electrode (RE) and platinum was used as counter electrode (CE). All potentials in this work are given with respect to the saturated calomel electrode (SCE). Several series of experiments were conducted to study corrosion-wear synergistic behaviors of the alloy: 1) Potentiodynamic test involving measuring polarization curves was initiated after a stable open potential. It was fulfilled with a potential sweep starting at -1 V and finishing at 1 V at a sweep rate of 1.67 mV/s. CHI software was used to analyze polarization data; 2) Corrosion-wear tests were carried out at open circuit potential and the evolution of open circuit potential was measured; 3) To analyze the synergistic effect between corrosion and wear, sliding wear tests polarized at -0.8 V were conducted and the transient current was measured.

3 Results and discussion

3.1 Electrochemical behavior

The evolution of open circuit potential (OCP) of Hastelloy C276 alloy under tribocorrosion is shown in Fig. 1. It can be obtained that at the start of sliding, open potential drops sharply down to more negative value due to friction. The cathodic shift phenomenon of OCP during corrosion-wear is frequently observed for

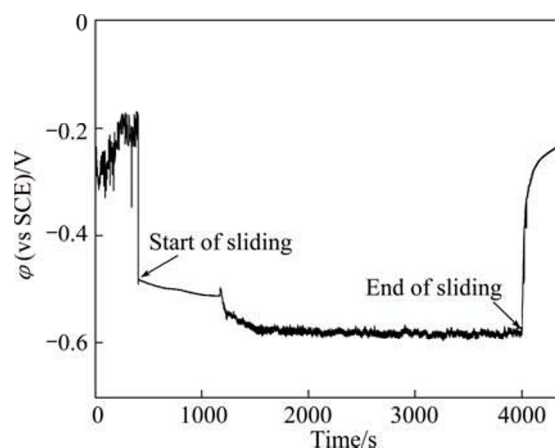


Fig. 1 Evolution of OCP of Hastelloy C276 alloy under tribocorrosion

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