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Wear resistance of Fe–28Al–3Cr intermetallic alloy under wet conditions

Garima Sharma [a,*], P.K. Limaye [b], M. Sundararaman [a], N.L. Soni [b]

[a] Material Science Division, BARC, Mumbai, 400 085, India
[b] Refuelling Technology Division, BARC, Mumbai, 400 085, India

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Abstract

Wear behaviour of iron aluminides (Fe–28Al–3Cr at.%) alloy has been investigated under wet conditions using ball on plate sliding wear tester. Wear resistance was examined against tungsten carbide (WC) ball sliding over the iron aluminide plate at room temperature. Wear tests were carried out at 3 N and 5 N load conditions at different sliding frequency of mating ball. The micromechanisms responsible for wear were identified to be microcutting, micropitting, and microcracking of deformed subsurface zones under wet conditions.

Keywords: Iron aluminide; Sliding wear; Wear; Intermetallics; Fe_3Al; Ordered structures

1. Introduction

Iron aluminides based on $D0_3$ or B2 ordered structure are now receiving extensive attention as materials with good potential for industrial applications and replacement for high temperature oxidation and corrosion resisting stainless steel [1,2]. In addition, these alloys offer low density and lower cost than many stainless steels. Furthermore, these compounds show high hardness and work hardening rate which mean that they can perform in severe wear and erosion conditions. The ordered structure inherent to these intermetallic alloys possess several attractive properties, among them are strength, stiffness and environmental resistance. In addition, the long range ordered superlattice reduces dislocation mobility, and at high temperature diffusional processes. This resulted in low ductility at room temperature and reduction in strength above 873 K which had retarded their development as structural materials. However, recent few studies have shown that the addition of Cr resulted in improving the ductility of iron aluminides immensely [3,4]. Addition of Cr also resulted in the improvement in corrosion resistance of these alloys [5]. Research efforts so far have been focused mainly on the enhancement of room temperature ductility together with the high temperature creep properties of these alloys. However, in wear related applications, loads are compressive in nature, therefore, tensile ductility is not as critical a mechanical property parameter as hardness, strength, and work hardening ability. A few recent studies have been done to study the dry abrasive wear resistance of nickel and iron aluminides [6–12]. The effect of Cr on the dry abrasive wear resistance of iron aluminides has already been studied in detail [13]. The abrasive wear resistance of Fe_3Al alloy has been shown to be comparable with the wear resistance of AISI 1060 carbon steel and SS 304 [8,9]. The abrasive wear of Fe_3Al compares favourably with that of Hadfield steel, a high toughness material used for the mining applications. The dry abrasion wear rate of iron aluminides varies slightly for B2 or DO_3 structures and Fe_3Al with DO_3 structure possesses marginally lower wear rate than those with B2 structure [8,9]. The wear resistance of iron aluminides with abrasive slurry has also been studied [14]. It has been well reported that the major reason for poor ductility of iron aluminides at ambient temperature is environment embrittlement involving moisture in air [15–19]. The presence of Cr in iron aluminides has been found to reduce the hydrogen embrittlement due to formation of electrochemical passive film on the surface [5,18]. Therefore, the present paper is an attempt to study the sliding wear resistance of Fe–28Al–3Cr alloy under pure water and to

* Corresponding author.
E-mail address: garimas@yahoo.com (G. Sharma).

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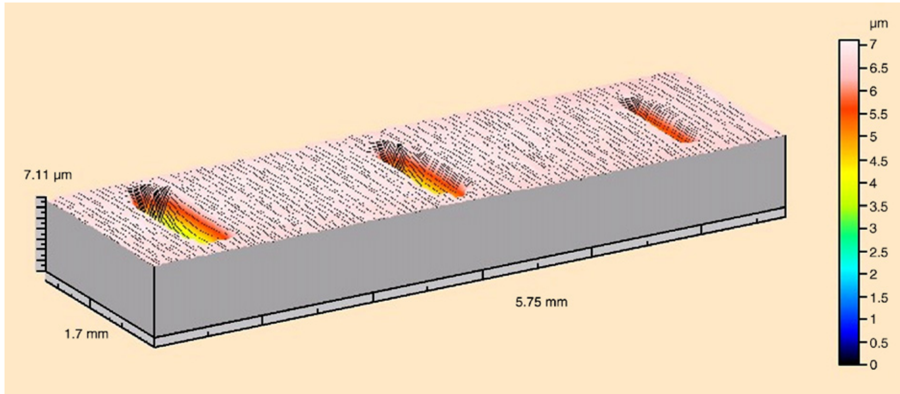

Fig. 1. 3-D profilometry of the wear groove of Fe–28Al–3Cr alloy at 3 N load and 21 Hz.

delineate the wear mechanisms during abrasion under wet conditions.

2. Experimental

The wear tests were performed on a micro-friction machine (TE 70 Plint) offering friction evaluation and wear testing facilities. Rolled sheets of iron aluminide of composition Fe–28Al–3Cr were heat treated at 540 °C for 170 h followed by furnace cooling to achieve DO_3 ordering at room temperature. Room temperature XRD analysis was performed to confirm DO_3 ordering in the sample. The sheets were cut into plates of 22 mm × 40 mm cross-section. These plates were metallographically polished to have an average surface roughness (Ra) of 0.23 μm. Wear tests were carried out in water at room temperature using a tungsten carbide ball of 6 mm diameter as a mating material. The abrasive tungsten carbide ball has a hardness of approx. 22 GPa and a fracture toughness of 7.0 MPa $m^{1/2}$. In order to retain uniform test conditions, a new ball was used for each test. The ball was made to slide on the plate sample with three frequencies (9, 15 and 21 Hz) keeping the sliding amplitude of 1 mm constant. The tests were performed with plate submerged in water all the time during testing. The tests were performed at 3 N and 5 N load conditions. Each test was repeated three times and wear volume was found to be within ± 1%. Wear track profiles were formed on the plate due to ball sliding. The wear profiles were studied by 3-D profilometry as shown in Fig. 1. Wear rate was calculated by dividing the volume of the wear groove by the sliding distance. The micromechanisms responsible for sliding wear were studied in detail by SEM.

3. Results and discussion

The variation of coefficient of friction during sliding is shown in Fig. 2. The friction value was found to increase very rapidly to 0.31 within few seconds of the start of the experiment. Though the coefficient of friction fluctuates slightly with sliding time, remain confined in the narrow range of 0.31 to 0.34. As expected, friction coefficient values under wet condition were much lower than those reported values of around 0.56–0.57 under dry conditions with same load and sliding frequency [13]. The presence of water during sliding forms a partial hydrodynamic film between the ball and the sample resulting in the reduction of the coefficient of friction. The steady state values of the coefficient of friction exhibit little dependence on the applied load, though the value at a lower load is slightly higher. The

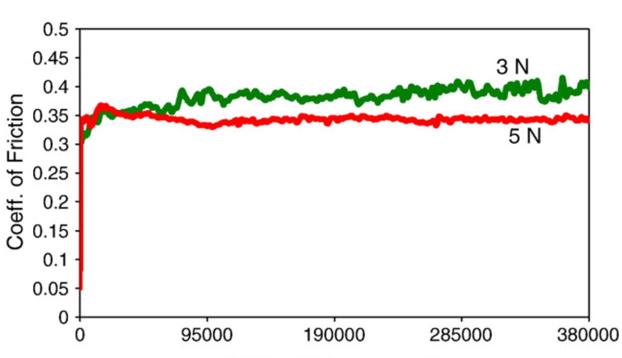

Fig. 2. Variation of coefficient of friction of Fe–28Al–3Cr alloy with sliding distance at different load.

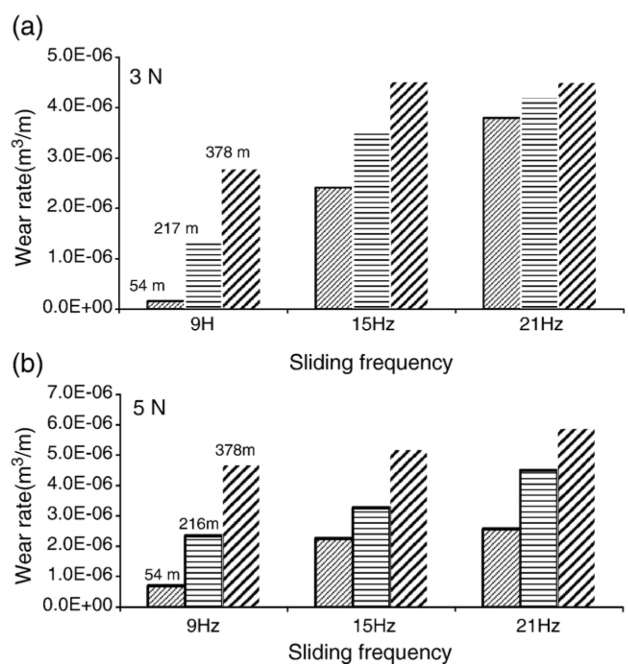

Fig. 3. Variation of wear rate with sliding frequency at (a) 3 N; (b) 5 N load, under static water.