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Impact fretting wear properties of 304 austenitic stainless steel against alumina in sodium sulfate solution

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ABSTRACT – The impact fretting wear of austenitic stainless steel was investigated with alumina balls as the counter materials on an impact fretting test rig in which the surface potential is controlled. The wear depth at OCP (Open Circuit Potential) was severer than that at cathode potentials (-1000 and -1200 mV vs. SCE), it often increased with non-contact time. This suggested that the fresh surface generated by contact significantly affected wear.

1. INTRODUCTION

The 304 austenitic stainless steel is widely used in nuclear reactors, hydraulic reciprocating pumps and many mechanical elements for its high corrosion resistance [1-2]. However, the severe wear at contact point occurs from time to time, leading to the reduced life-time.

In this research, to investigate the wear properties of the nuclear reactor, we used an impact fretting test rig to mimic the real contact in nuclear reactors. A potentiometer is equipped to monitor the electro-chemical potential on the specimen surfaces in corrosive solutions. This paper describes the impact fretting corrosive wear experiment of 304 austenitic stainless steel against alumina.

2. EXPERIMENTAL

The schematic diagram of the impact fretting test rig developed in this study is shown in Figure 1. The upper ball specimen was fixed at the end of the vertical shaft with resin cap oscillating in the Z direction. The Al2O3 ball (φ6.4mm, Ra:0.1□m, HV:1800) was used to avoid an electrical contact. The lower specimen of 304 stainless steel pin (φ:10mm, Ra:0.02-0.05□m, HV:220) was fixed on the horizontal stage oscillating in the X direction. Both X and Z motions were controlled by piezo actuators, respectively. The X direction motion was measured by an eddy current transducer. The impact force and tangential force were measured with load cell.

Experimental conditions are listed in Table 1. In this paper, to clarify the effect of corrosion in impact fretting wear, the interval time for each collision was controlled (Figure 2), the non-contact time per an impact change accordingly. In the impact fretting test, the exposed fresh surface surely comes into contact with the solution. Therefore, it is considered that the wear characteristics are significantly affected by the duration time of the non-contact state.

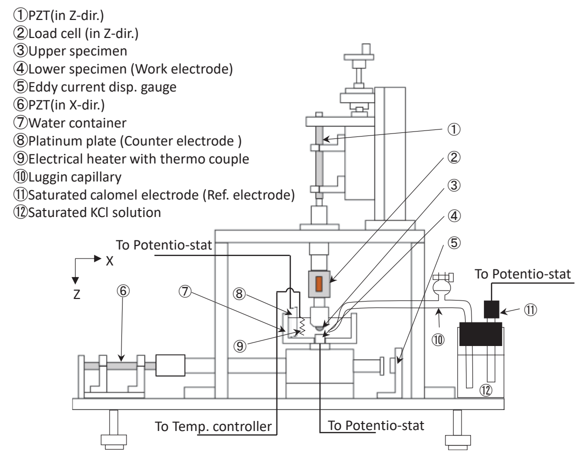

Figure 1 Schematic diagram of the impact fretting test rig.

Table 1 Experimental conditions for impact fretting test.

Impact load, N	3
Amplitude in X dir., μm	50
Interval time, ms	0, 20, 50, 100, 200, 1000
Frequency in X dir., Hz	10, 25, 50
Temperature, °C	30
Solution	Na_2SO_4 aq. 0.1mol/L
Potential (vs. SCE), mV	-1200, -1000, OCP
Number of cycles	50000

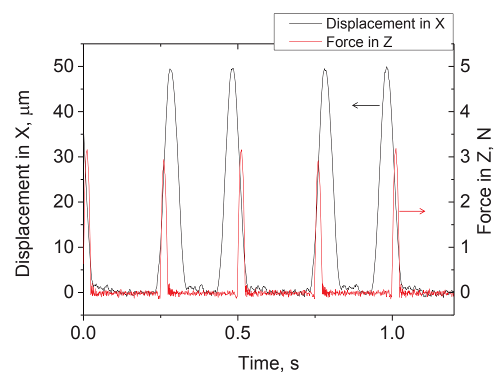

Figure 2 Measurement of displacement in X dir. and contact force in Z dir. (Impact load: 3N, Amp. in X dir.: 50μm, Frequency in X dir.: 10Hz, Interval time: 200ms).

3. RESULTS AND DISCUSSION

The typical results of impact-fretting wear are shown in Fig. 3. At 10 Hz and at 25 Hz in X direction oscillation frequencies, the wear increases with the oxidation time at OCP (Open circuit potential). The high wear of OCP is due to the mechanical wear which exposes the fresh surface to the solution leading to the continuous corrosion reaction and anodic dissolution. Also, the wear depends on non-contact time, so the wear progressed by repeating the cycle of passivation and de-passivation. On the other hand, the wear in cathodic potentials such as -1200mV or -1000mV (vs. SCE) is negligible small (less than 0.5μm), and also is independent of the oxidation time. The corrosion reaction on the wear surface was inhibited at the cathode potential. Therefore, these results indicate that the corrosion effect of fresh surface is dominant in impact-fretting wear at OCP in this study. However, at a frequency of 50Hz and a non-contact time over 50ms, the wear was lower than the ones of other frequencies, also the effect of non-contact time was very slight.

Figure 4 shows the surface potential of stainless steel in the impact fretting test. After cathodic treatment at -1500 mV, it is switched to the OCP, the passivation progresses and the surface potential increases. When the wear test started, the potential dropped rapidly, this drop suggests that the polarization was caused by the exposure of the fresh surface. After then, the potential recovered immediately at the end of test. Hence, this curve can qualitatively represent the electro-chemical state of the specimen surface. Figure 5 summarizes the average value of the surface potential during the wear test. These potentials at 25 and 50 Hz tends to increase with non-contact time. It means that the polarization level on wear decreases with increasing non-contact time, this decreasing was caused by a reduction of the removal rate of corrosion products by a single impact. Generally, the film thickness of the corrosion product increases with time. Therefore, this thickness increased with the duration time of non-contact, the removal efficiency of the corrosion products could be decreased. On the other hand, at a frequency of 10 Hz, these potentials are relatively lower than the ones of 25 and 50 Hz, and the high wear was shown at over 100 ms (Fig. 3). These results could be suggested the effect of the squeezing film due to oscillation in the Z direction. The real contact area of the wear surface decreased with the increase in the frequency in the Z direction.

4. CONCLUSIONS

The impact fretting wear tests were performed to examine the chemical effect on wear of 304 austenitic stainless steel in Na_2SO_4 solution.

(a) The wear in cathodic potentials such as -1200mV or -1000mV (vs. SCE) is negligible small (less than 0.5μm) due to inhibit the corrosion reaction.

(b) At frequencies of 10 and 25 Hz in X direction the wear depths increased with the non-contact time.

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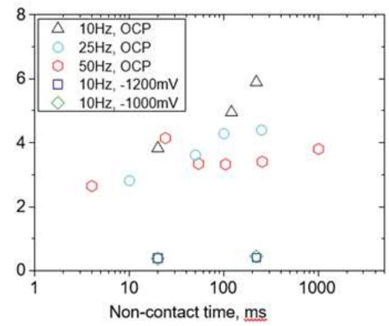

Figure 3 Relationships between the maximum wear depth and the non-contact time of 304 stainless steels against Al_2O_3 ball in Na_2SO_4 solution (Temp. at 30˚C, Impact load at 3N, Amp. at 50μm).

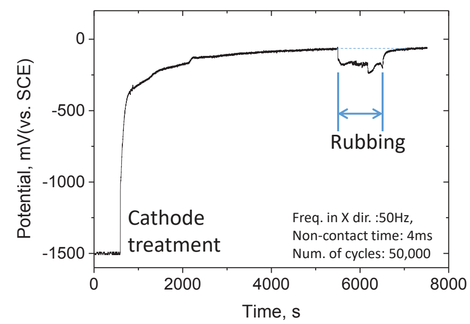

Figure 4 Surface potential of 304 stainless steel in impact fretting wear test (Temp. at 30˚C, Impact load at 3N, Amp. at 50μm).

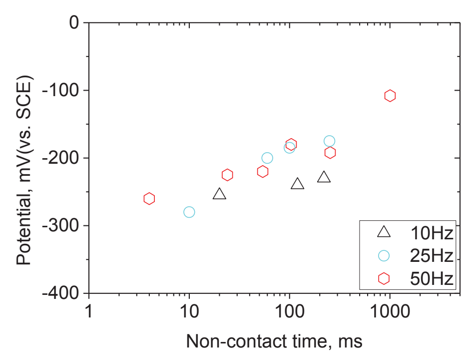

Figure 5 Average surface potentials of 304 stainless steels under impact fretting in Na_2SO_4 solution (Temp. at 30˚C, Impact load at 3N, Amp. at 50μm).

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