Fretting Corrosion Analysis of 316L Stainless Steel (316LSS) under 240 Grit, 320 Grit and 600 Grit Surface Roughness

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Introduction: Mechanically assisted corrosion is a continuing concern with all metallic implant materials. When mechanical abrasion occurs, the passive oxide film is disrupted and this can accelerate the corrosion process. Factors such as mechanical, electrochemical, geometrical, material and solution conditions may all influence the behavior [1] [2]. In this study, 316L stainless steel (316LSS) (ASTM F138) was investigated using a pin-on-disk test for its fretting corrosion behavior. The effect of surface roughness was investigated in phosphate buffer saline (PBS) at pH 7.4.

Methods: For this experiment, the test samples consisted of a flat circular disk and cone shaped flat bottom pin made out of 316L stainless steel. Both the pin and disc were polished and then sonicated in ethanol for 10 minutes. Samples were polished to 240, 320 and 600 grit to investigate the difference in response due to roughness. The test areas of pin and disk were controlled using an acrylic coating to expose only the contact region to the solution environment. The surfaces were aligned such that grit lines lay perpendicular to each other. All experiments were performed at room temperature in PBS, at 50 um displacements and at a fretting frequency of 1.25 Hz. During fretting, the load, coefficient of friction (COF), motion and currents were continuously monitored and recorded for all experiments. A load test was conducted by varying the normal load from 0.5N to 30N (or until the stick condition was reached) at a fixed potential of 0 V (vs. Ag/AgCl) for 240 Grit, 320 Grit and 600 Grit material couples. Repeated tests to the same test area were performed at different load magnitudes without separating the pin and disk surfaces. For each test, the data analysis included calculation of the average fretting current and the coefficient of friction (COF). Post-test surface characterization of the pin and disk samples were performed using Scanning Electron Microscopy (SEM) for damage assessment. Where appropriate, statistical analysis of the results was performed using ANOVA methods.

Results: *Loading Tests:* For all different grits used the fretting COF starts at a high value and drops to about 0.2 to 0.3 and stays constant at the higher loads (Fig. 1a). The average fretting current increased with increasing loads and the maximum values were different for each of the grit samples (Figure 1b). Statistical analysis showed small differences in COF and average fretting current with load ($p<0.05$). The maximum average current value dropped with increasing grit value, with the 240 samples showing a maximum current value of 5uA and the 600 grit samples showing a maximum value of approximately 1uA. Run-away pitting was observed in the raw data of the current vs. time. It was observed that as the grit increased, the run-away current occurred sooner and at lower loads. Pitting appeared to occur more in higher grit samples than at lower grit values, which was observed within SEM Images.

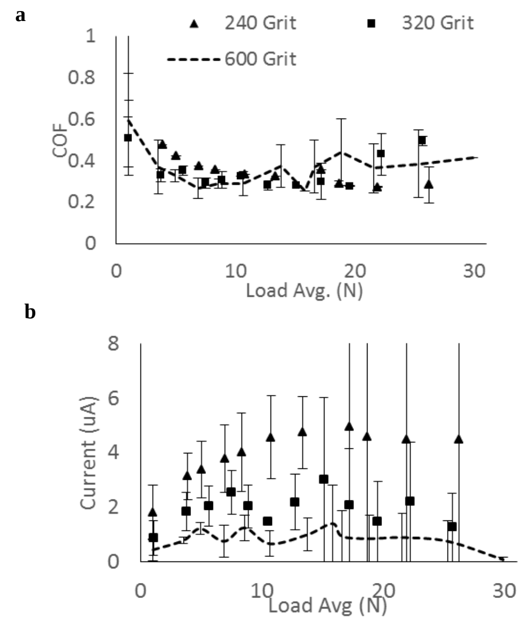

Fig. 1: (a) avg. COF and (b) avg. fretting current v/s avg. load.

Discussion: As seen in Figure 1a, the COF is at a maximum value in the range of 1-0.5 at the lowest loads. With increasing load, the value drops and this behavior is consistent across all the grits, demonstrating the independence of COF on surface roughness. However, the fretting currents are dependent on the surface roughness, with the lowest grit (240) exhibiting higher current values (Figure 1b). This could be explained by the crevice formation within the interface, leading to a more aggressive environment in terms of local solution conditions [2]. Pitting was also observed to increase with a decrease in the surface roughness. The crevice effects become more pronounced at the 600 grit, as the perpendicular alignment of the grit lines allows for smaller and more aggressive crevice conditions due to solution entrapment. The pin-on-disk fretting corrosion test can capture detailed mechanical, electrochemical and structural interactions present and provides an excellent means to evaluate these processes.

Conclusions: Variable load tests were conducted on 316L stainless steel coupled with itself with samples at 240 grit, 320 grit and 600 grit. The results demonstrate the dependence of fretting currents on surface roughness as well as load magnitudes. However, coefficient of friction (COF) is not affected by the surface roughness, but shows a decrease in value with increasing load magnitudes. Further investigation of the fretting current dependence on roughness is required.

References: **1.** Swaminathan V; Gilbert JL; Biomaterials 2012: 33 5487-5503, **2.** Gilbert JL; Buckley CA; Jacobs JJ; J Biomed Mat Res 1993:27 1533-44

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