Biomaterials 33 (2012) 5487–5503

Contents lists available at SciVerse ScienceDirect

Biomaterials

journal homepage: www.elsevier.com/locate/biomaterials

Fretting corrosion of CoCrMo and Ti6Al4V interfaces

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ARTICLE INFO

Article history:
Received 21 March 2012
Accepted 4 April 2012
Available online 9 May 2012

Keywords:
Tribocorrosion
Metallic biomaterials
Metal-on-metal
Friction
Fretting corrosion model
Modularity

ABSTRACT

Mechanically assisted corrosion (fretting corrosion, tribocorrosion etc.,) of metallic biomaterials is a primary concern for numerous implant applications, particularly in the performance of highly-loaded medical devices. While the basic underlying concepts of fretting corrosion or tribocorrosion and fretting crevice corrosion are well known, there remains a need to develop an integrated systematic method for the analysis of fretting corrosion involving metal-on-metal contacts. Such a method can provide detailed and quantitative information on the processes present and explore variations in surfaces, alloys, voltages, loadings, motion and solution conditions. This study reports on development of a fretting corrosion test system and presents elements of an in-depth theoretical fretting corrosion model that incorporates both the mechanical and the electrochemical aspects of fretting corrosion. To demonstrate the capabilities of the new system and validate the proposed model, experiments were performed to understand the effect of applied normal load on fretting corrosion performance of Ti6Al4V/Ti6Al4V, CoCrMo/Ti6Al4V, and CoCrMo/CoCrMo material couples under potentiostatic conditions with a fixed starting surface roughness. The results of this study show that fretting corrosion is affected by material couples, normal load and the motion conditions at the interface. In particular, fretting currents and coefficient of friction (COF) vary with load and are higher for Ti6Al4V/Ti6Al4V couple reaching 3 mA/cm^2 and 0.63 at about 73 MPa nominal contact stress, respectively. Ti6Al4V coupled with CoCrMo displayed lower currents (0.6 mA/cm^2) and COF (0.3), and the fretting corrosion behavior was comparable to CoCrMo/CoCrMo couple (1.2 mA/cm^2 and 0.3, respectively). Information on the mechanical energy dissipated at the interface, the sticking behavior, and the load dependence of the inter-asperity distance calculated using the model elucidated the influence of mechanical factors on the experimental results. It was observed that the lowest amount of work was required to generate some of the highest fretting corrosion currents in Ti6Al4V/Ti6Al4V couples compared to the other combinations. The elements of the model presented here provide an excellent basis to explain many of the observed behaviors of these interfaces.

1. Introduction

Mechanically assisted corrosion, of which there are several types including stress-assisted corrosion, wear-assisted corrosion (tribocorrosion), fretting corrosion, and fretting crevice corrosion, is a continuing concern with all metallic implant materials, including those of orthopedic, spinal, dental and even cardiovascular devices. It is well known that mechanical disruption of passive oxide films on metallic biomaterial surfaces can accelerate corrosion processes and can have deleterious effects in-vivo [1–6]. The rate and severity of such corrosion processes can be influenced by combination of several factors that include but are not limited to mechanical, electrochemical, geometrical, material, and solution conditions. Fretting crevice corrosion of modular taper interfaces, which are typically comprised of CoCrMo/Ti6Al4V, Ti6Al4V/Ti6Al4V or CoCrMo/CoCrMo couples, represent a particularly important area of implant degradation.

Recognizing the importance of tribocorrosion in implant degradation, several triboelectrochemical test methods have been developed over the years that involve sliding contacts under well defined loading and displacement conditions [7–12]. In these methods, the contact materials typically include a metallic biomaterial sliding against alumina or other ceramic counter body exposed to aqueous solutions and the motion conditions range from unidirectional, circular, reciprocating, and fretting type of motion. In such test methods the most commonly used electrochemical measurements involve monitoring the open circuit

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doi:10.1016/j.biomaterials.2012.04.015