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Influence of loose PMMA bone cement particles on the corrosion assisted wear of the orthopedic AISI 316LVM stainless steel during reciprocating sliding

Fatima Zivic*, Miroslav Babic, Nenad Grujovic, Slobodan Mitrovic, Dragan Adamovic

Faculty of Engineering, University of Kragujevac, Sestre Janjic 6, 34000 Kragujevac, Serbia

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ABSTRACT

Corrosion assisted wear behavior of orthopedic AISI 316LVM stainless steel is explored by using tribological tests and SEM/EDS analysis. Wear mechanisms were investigated in three different environments, under reciprocating sliding at micro-loads. Variation of the sliding speed was also observed. Samples were subjected to the dry sliding, sliding in Ringer's solution and in Ringer's solution containing PMMA bone cement particles. Influence of the loose PMMA particles on the corrosion and wear of the orthopedic AISI 316LVM stainless steel during reciprocating sliding was investigated.

Experimental data showed that the presence of the cement particles in Ringer's solution had deleterious influence on the wear of the 316LVM steel. Cement particles were embedded into the surface of the flat steel sample and represented non-metallic inclusions highly contributing to the increase of the corrosion assisted wear process. Pitting, crevice corrosion and stress corrosion cracking (SCC) were all observed on the steel samples, especially under the lowest applied load (100 mN). Governing wear mechanism was abrasive wear together with corrosion assisted wear in wet environments. Plastic deformation controlled wear was observed for the higher loads (250–1000 mN). Sliding speed showed no influence on the wear level.

1. Introduction

Metallic implant materials made of stainless steel have found many applications as medical devices [1–4]. The first metals used for orthopedics was the stainless steels [5], because of their excellent mechanical properties such as fracture toughness, fatigue strength and cost effectiveness. The cost of 316L stainless steels is significantly lower than other used metallic biomaterials, even down to one-tenth of the price of other ones [6,7]. However, their wear resistance and corrosion determine their durability. Wear debris from the contact of articulating surfaces in artificial joints still represent a challenge in implants design from many aspects, such as cellular response or ways of surfaces destruction. Metallic ions release, such as nickel, provokes extremely unwanted reactions of the living tissue. The form of stainless steel designated 316L is commonly used for orthopedic purposes (American Society for Testing and Materials F138, ASTM F138). 316L stainless steel is used for: cranial plates, orthopedic fracture plates, dental implants, orthodontic archwires, spinal rods, joint replacement prostheses, coronary stents and catheters. In early 60s Charnley used PMMA and stainless steel for total hip replacement [8]. 316L stainless steel is often used for coronary stents [9]. Stainless steel has many advantages, such as stability of shape in long term and strength, but it also can cause severe problems related to allergies due to metallic ions.

316L stainless steel is often used in a surgical procedure for the treatment of the degeneration of the intervertebral disc, when the damaged disc is removed completely and replaced with an implant made from a combination of metal and plastic, which serves to mimic the normal movement of the lumbar and the spine [10]. Cervical disc arthroplasty implant is subjected to complex motions during its service life (both sliding and rolling) during flexion/extension rotation of the cervical spine [2]. Even though stainless steel is not recommended for metal elements of artificial hip joints [11], it is still used in practice, mainly due to its low price. Sliding wear of the joint system elements is characterized by a complex multidirectional motion. Generally, *in vivo*, implants are subjected to discontinuous cyclic loading over a period of many years. The fatigue resistance to fracture of these implants is primarily a function of the number of cycles and stress and investigations related to the behavior at low and high cycle fatigue loading is important [12,13].

Studies show that the most steel implants failures (more than 90%) are due to the pitting and crevice corrosion attack [5,14–16].

* Corresponding author. Tel.: +381 34 335 990x644; fax: +381 34 333 192.
E-mail addresses: zivic@kg.ac.rs (F. Zivic), babic@kg.ac.rs (M. Babic), gruja@kg.ac.rs (N. Grujovic), boban@kg.ac.rs (S. Mitrovic), adam@kg.ac.rs (D. Adamovic).

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