Research paper

The effect of microstructure on fatigue performance of Ti–6Al–4V alloy after EDM surface treatment for application in orthopaedics

Josef Stráský, Miloš Janeček, Petr Harcuba, Michal Bukovina, Lothar Wagner

Charles University, Department of Physics of Materials, Prague, Czech Republic
University of Žilina, Department of Materials Engineering, Žilina, Slovak Republic
Clausthal University of Technology, Institute of Materials Science and Engineering, Germany

ARTICLE INFO

Article history:
Received 31 January 2011
Received in revised form 24 May 2011
Accepted 21 June 2011
Published online 30 June 2011

Keywords:
Fatigue endurance
Ti–6Al–4V
Electric discharge machining
Surface roughness

ABSTRACT

Three different microstructures – equiaxed, bi-modal and coarse lamellar – are prepared from Ti–6Al–4V alloy. Electric discharge machining (EDM) with a high peak current (29 A) is performed in order to impose surface roughness and modify the chemical composition of the surface. Detailed scanning electron microscopy (SEM) investigation revealed a martensitic surface layer and subsurface heat affected zone (HAZ). EDX measurements showed carbon enriched remnants of the EDM process on the material surface. Rotating bending fatigue tests are undertaken for EDM processed samples for all three microstructures and also for electropolished – benchmark – samples. The fatigue performance is found to be rather poor and not particularly dependent on microstructure. The bi-modal microstructure shows a slightly superior high cycle fatigue performance. This performance can be further improved by a suitable heat treatment to an endurance limit of 200 MPa.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Natural 'big' joints (e.g. hip and knee joints) are complex structures that operate under critical conditions. Human joints undergo degenerative diseases resulting in the degradation of mechanical properties. Total joint replacement is the ultimate solution when the natural joint cannot operate appropriately. Replacement of big joints is considered a major achievement in orthopaedic surgery; however, appropriate implant material is also a challenge for material scientists. The demand for long lasting implants is expected to increase heavily (Geetha et al., 2009). Biocompatibility, corrosion and mechanical properties, namely fatigue endurance, must be considered for hard tissue replacement materials (Niinomi, 2008). The excellent biocompatibility of titanium has been proved by many authors both in vitro and in vivo (Okazaki and Gotoh, 2005; Palmquist et al., 2009). A major advantage of the newly developed biocompatible beta titanium alloys is their low elastic modulus that prevents bone reabsorption and associated loosening. However, the elastic modulus effects are not discussed in this study and therefore, the well-known Ti–6Al–4V alloy is considered. This alloy is still the most