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ORIGINAL PAPER

Tribological Behaviour of Orthopaedic Ti-13Nb-13Zr and Ti-6Al-4V Alloys

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Abstract The aim of this study is to compare the tribological behaviour of novel orthopaedic implant alloy Ti-13Nb-13Zr with that of the standard Ti-6Al-4V ELI alloy, available in four different microstructural conditions produced by variations in the heat treatments. The friction and wear tests were performed by using a block-on-disc tribometer in Ringer's solution at ambient temperature with a normal load of 20–60 N and sliding speed of 0.26–1.0 m/s. It was found that variations in microstructures produced significant variations in the wear resistance of Ti-6Al-4V ELI alloy. The wear losses of materials solution treated (ST) above the β transus temperature are significantly lower compared with those of materials ST in the $(\alpha + \beta)$ phase field and are almost insensitive to applied load and sliding speed. Wear loss of the $(\alpha + \beta)$ ST Ti-6Al-4V ELI alloy continuously increased as applied load was increased and was highest at the highest sliding speed. The Ti-6Al-4V ELI alloy in all microstructural conditions possesses a much better wear resistance than cold-rolled Ti-13Nb-13Zr alloy. Friction results and morphology of worn surfaces showed that the observed behaviour is attributed to the predominant wear damage mechanism.

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1 Introduction

Amongst biometallic materials, titanium alloys are the most suitable for use in implants that replace hard tissue [1–3]. They have long been used as an implant material for artificial joints, e.g. hip, knee or shoulder joints, because of their attractive mechanical properties and biochemical compatibility. The Ti-6Al-4V alloy is established as one of the major titanium alloys used for orthopaedic implants. This $(\alpha + \beta)$ titanium alloy was originally designed to be used in aerospatial and naval industries, but afterwards it was adopted for biomedical applications [4, 5]. Its excellent combination of high strength, low density, low elastic modulus, good fatigue resistance, enhanced corrosion resistance and superior biocompatibility makes this alloy an ideal choice for biomedical devices [6, 7].

The standard Ti-6Al-4V alloy is normally used in solution annealed condition. However, the mechanical response of the Ti-6Al-4V alloy is greatly influenced by microstructure. It has been shown that better performance can be achieved through microstructure control. Depending upon the solution treatment temperature, cooling rate and final ageing temperature, the α/β volume fraction and morphology may change [3, 6, 7]. As a result, the distinct microstructures can be produced in the Ti-6Al-4V alloy, providing the enhancement of mechanical properties required for biomedical applications. Extensive study performed on the effect of microstructure on these properties, as described by Geetha et al. [7], has shown that equiaxed microstructure possesses best combination of mechanical properties in the $(\alpha + \beta)$ alloys. Further enhancement may