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Research paper

Strength enhancement of a biomedical titanium alloy through a modified accumulative roll bonding technique

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ABSTRACT

The strength of a biomedical β-type alloy, Ti–25Nb–3Zr–3Mo–2Sn, was enhanced through severe plastic deformation using a modified accumulative roll bonding technique. Incremental strength increases were observed after each cycle, while ductility initially fell but showed some recovery with further cycles. After 4 cycles there was a 70% improvement in the ultimate tensile strength to 1220 MPa, a two-fold increase in the 0.5% proof stress to 946 MPa and the ductility was 4.5%. The microstructure comprised of ultrafine grain β grains heavily elongated in the rolling direction with a fine dispersion of nanocrystalline α phase precipitates on the β grain boundaries. Shear bands formed in order to accommodate large plastic strains during processing and the grains within the bands were significantly finer than the surrounding matrix.

1. Introduction

Due to their high strength to weight ratio, excellent toughness, corrosion resistance and biocompatibility, titanium and its alloys are favoured for a wide range of biomedical applications (Collings, 1984). There is considerable research focussed on development of new β titanium alloys for biomedical applications because of their favourable property set in combination with compositions absent of Ni and other toxic elements (Kim et al., 2005b; Hao et al., 2007a; Niinomi et al., 2007). As well as being biocompatible, Ti alloys for surgical implants need to be mechanically compatible (Niinomi, 2008). For orthopaedic implants high strength in conjunction with a low elastic modulus is critical in order to reduce detrimental "stress shielding" effects. For other applications, such as stents or fasteners, properties such as strength and fatigue resistance are of primary importance.

A near β Ti alloy containing the non-toxic elements Nb, Zr, Mo and Sn was developed by the authors as a biomedical alloy suitable for implant applications (Kent et al., 2010; Paludugu et al., 2010). The Ti–25Nb–3Zr–3Mo–2Sn alloy has a low modulus of elasticity, high strength and exhibits considerable plasticity and pseudoelastic character. The alloy also shows excellent characteristics in the cast form, with ductility exceeding 30% and strengths in excess of 900 MPa after ageing (Paludugu et al., 2010). In comparison to other Ti–Nb based

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