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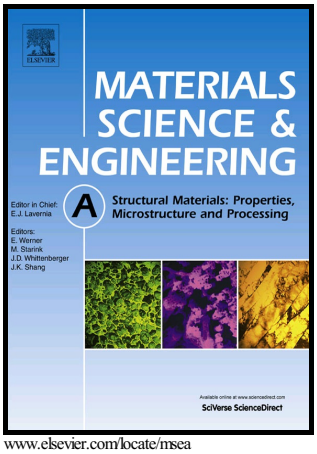

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PII: S0921-5093(17)31559-9
DOI: https://doi.org/10.1016/j.msea.2017.11.098
Reference: MSA35813

To appear in: *Materials Science & Engineering A*

Received date: 22 August 2017
Revised date: 22 November 2017
Accepted date: 23 November 2017

Cite this article as: Ajit Pal Singh, Fei Yang, Rob Torrens and Brian Gabbitas, Solution Treatment of Ti-6Al-4V Alloy Produced by Consolidating Blended Powder Mixture using a Powder Compact Extrusion Route, *Materials Science & Engineering A,* https://doi.org/10.1016/j.msea.2017.11.098

Solution Treatment of Ti-6Al-4V Alloy Produced by Consolidating Blended Powder Mixture using a Powder Compact Extrusion Route

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Abstract: Titanium alloys are very sensitive to thermal history and different microstructures are obtained depending on their chemistry, processing route and post-processing heat treatment. The objective of this paper is to characterise solution-treated Ti-6Al-4V alloy rods from microstructural investigations using optical and transmission electron microscopy (TEM) in addition to measurements of chemical composition and levels of impurity oxygen. From the results, it is clear that the compositions and oxygen concentration of the different rods, which varied between 0.34-0.36 wt.%, was consistent from one extrusion to another. TEM analysis of the as-extruded material with a fine lamellar microstructure indicates that the severe deformation and attendant dynamic recrystallization during and after hot extrusion did not give rise to any undesirable features that can degrade the ductility. Solution treatment above the β transus and subsequent ageing causes grain growth with grains containing a metastable martensitic structure (only α' phase was present), some retained β and a limited formation of acicular secondary α. The α+β quenched and aged treatment gives a lamellar type morphology, but at the α interfaces there is retained β with some secondary α and potentially some α' phase. In terms of mechanical behaviour, the data from v-notch Charpy impact tests and non-standard micro-tensile testing suggests that both water quenched and aged microstructures give a higher yield strength (~1022-1033 MPa) and micro-hardness (388 HV), while the fracture-related properties such as estimated plastic strain and impact toughness were between 5-6% and 13.7 J respectively. Overall, the level of mechanical properties reported here is better than that for typical values reported in the literature for as-cast material after similar solution treatments.

Keywords: Powder metallurgy, vacuum sintering and extrusion, quenching and ageing, microstructure, impact toughness, fracture behaviour

Introduction: Solution treatment/quenching from either the β or α+β phase regions, followed by ageing, is thought to be an effective way of enhancing tensile strength and hardness at the expense of ductility and toughness [1-4]. However, there are a number of studies which suggest that microstructures developed by quenching Ti-6Al-4V alloy can provide a good balance of mechanical properties [5-7]. Imam and Gilmore reported that an as-quenched microstructure for ingot Ti-6Al-4V alloy, after quenching from 900°C, gives a better fatigue life in addition to good ductility, tensile strength and elastic modulus [5]. For powder produced Ti-6Al-4V alloy, Yang and Gabbitas showed that quenching from 960°C with a holding time of an hour gives a microstructure which is capable of providing high strength while maintaining a good level of ductility [6]. Similarly work done by Jia et al. demonstrates that a unique microstructure obtained by quenching and ageing of a Ti-6Al-4V alloy prepared by powder compact forging with a relatively high oxygen content of 0.52 wt.% can provide a very high yield strength (YS) and ultimate tensile strength (UTS) along with elongation to fracture of 7.2% [7]. Thus, it is evident that solution treatment and water quenching Ti-6Al-4V can give rise to high strength while maintaining a good level of ductility. There are no previously reported studies in the literature which describe the effect of a quenched and aged microstructure on impact toughness of severely deformed Ti-6Al-4V alloy produced using powder metallurgy (PM). Thus, understanding the effect of β or α+β quenching plus appropriate ageing treatments on the structure and properties of Ti-6Al-4V alloy is important for optimising