

Optimization of a Harmonic Structured Ti-24Nb-4Zr-8Sn Alloy through Combined Microstructural and Mechanical Investigations

Benoit Fer, David Tingaud, Frédéric Prima, Guy Dirras

► To cite this version:

Benoit Fer, David Tingaud, Frédéric Prima, Guy Dirras. Optimization of a Harmonic Structured Ti-24Nb-4Zr-8Sn Alloy through Combined Microstructural and Mechanical Investigations. PMTi 2024, Sep 2024, Madrid, Spain. pp.8-9. hal-04760926

HAL Id: hal-04760926 https://hal.science/hal-04760926v1

Submitted on 30 Oct 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Optimization of a Harmonic Structured Ti-24Nb-4Zr-8Sn Alloy through Combined Microstructural and Mechanical Investigations

B. Fer^{1,2,a*}, D. Tingaud^{1,b}, F. Prima^{2,c}, G. Dirras^{1,d}

¹ Université Sorbonne Paris Nord, Laboratoire de Sciences des Procédés et des Matériaux, CNRS, UPR 3407, 99 avenue JB Clément, 93430 Villetaneuse, France.

²PSL University, ChimieParisTech, CNRS, Institut de Recherche de Chimie Paris, 75005 Paris, France

*now at DMAS, ONERA, Université Paris Saclay, F-92322 Châtillon, France

^{a*}ferbenoit@gmail.com, ^bdavid.tingaud@univ-paris13.fr, ^cfrederic-prima@chimie-paristech.fr, ^ddirras@univ-paris13.fr

Keywords: Harmonic structure, Powder Metallurgy, Spark Plasma Sintering, Mechanical properties, Plastic deformation mechanisms

Abstract. Heterogeneously structured materials have benefited many recent developments because of their potential to reach a good compromise between strength and ductility. Among them, this work focuses on harmonic-structured materials, which consist of a volume network of soft core and hard shell regions in the material [1]. Such a design was applied on a Ti-24Nb-4Zr-8Sn alloy - which belongs to the β -metastable titanium alloys family. The aim is to master the processing route and investigate a possible improvement of mechanical properties induced by the harmonic design, for a use of Ti-24Nb-4Zr-8Sn alloy as a hip implant constituent.

The powder metallurgy (PM) processing route includes a Ball Milling stage of spherical and pre-alloyed powder particles, followed by a consolidation step using Spark Plasma Sintering. An oxygen contamination could occur during the fabrication route, and the consequences of such enrichment were first evaluated on the microstructure. Then, an optimization of harmonic-structured Ti-24Nb-4Zr-8Sn was performed by combining specific fabrications together with complete microstructural characterizations and mechanical testings of the obtained samples. Typical Ti-24Nb-4Zr-8Sn harmonic microstructures are shown in Figure 1. It proved a significant contribution of the harmonic design on yield strength of the alloy without a drastic loss of ductility, if the shell fraction does not exceed a threshold value. Grain size differences between core and shell can also be controlled during the process and high differences are required for an improved mechanical behaviour.

Besides, interrupted quasi-static compression tests were performed to observe the microstructure evolution by ex-situ Scanning Electron Microscopy, Electron BackScatter Diffraction (EBSD) and X-Ray Diffraction (XRD). It highlights the formation and propagation of dislocations during plastic deformation: a very high density was detected with XRD after compression deformation. Some of them are Geometrically Necessary Dislocations which pile up at core-shell interfaces, as highlighted by EBSD results at intermediate strain percentages. Pile-ups of dislocations create at this location a misoriented area thereafter called Interface Affected Zone. It contributes to increase the value of the hetero-deformation induced stress – or back stress - which appears during deformation and leads to the global hardening of the material [2].

Finally, these experiments allow to optimize the PM processing route, discuss the mechanical properties of the harmonic-structured Ti-24Nb-4Zr-8Sn alloy, and understand the corresponding plastic deformation mechanisms.



Fig. 1. EBSD Inverse Pole Figure maps of harmonic-structured Ti-24Nb-4Zr-8Sn obtained by varying Ball Milling parameters.

References

- Harmonic structure, a promising microstructure design. K. Ameyama, F. Cazes, H. Couque, G. Dirras, S. Kikuchi, J. Li, F. Mompiou, K. Mondal, D. Orlov, B. Sharma, D. Tingaud and S K. Vajpai, Materials Research Letters, Volume 10, Issue 7 (2022)
- [2] Perspective on hetero-deformation induced (HDI) hardening and back stress. Y. Zhu and X. Wu, Materials Research Letters, Volume 7, Issue 10 (2019)