THERMOMECHANICAL BEHAVIOR OF GUM METAL UNDER CYCLIC LOADING

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1. Introduction

This work presents thermomechanical characterization of a new multifunctional class of β-Ti alloy called Gum Metal subjected to cyclic tensile loading. Being developed in the Toyota Central R&D Laboratory (CRDL), Gum Metal has attracted remarkable attention due to its exceptional properties, i.e. low elastic modulus, high strength, nonlinear elastic deformation, excellent cold workability as well as Invar- and Elinvar-like behavior [1]. Typical composition of Gum Metal is Ti-Nb-Ta-Zr-O, where oxygen content plays a key role. Its fabrication route consists of powder metallurgy forging method with subsequent cold working usually up to 90% in area reduction. The latter is critical for the unique mechanical performance but deformation mechanisms occurring in Gum Metal are unconventional and still unclear [1, 2].

2. Experimental details

In this study, Gum Metal with composition Ti-23Nb-0.7Ta-2Zr-1.2O (at.%) provided by CRDL has been subjected to cyclic tension loading. Force vs. strain curves have been obtained with high accuracy by the MTS 858 testing machine, while the temperature changes of the specimen have been estimated by the fast and sensitive infrared camera Phoenix FLIR Co. in a contactless manner. Thermomechanical couplings accompanying the loading-unloading tension cycles and deformation processes have been analyzed in order to estimate the range of reversible deformation.

3. Results and discussion

Comparison of force vs. strain curves obtained for subsequent tension cycles at strain rate of $4x10^{-4}s^{-1}$ with a step of 0,002 is presented in Fig. 1 (14 loading-unloading cycles until rupture).

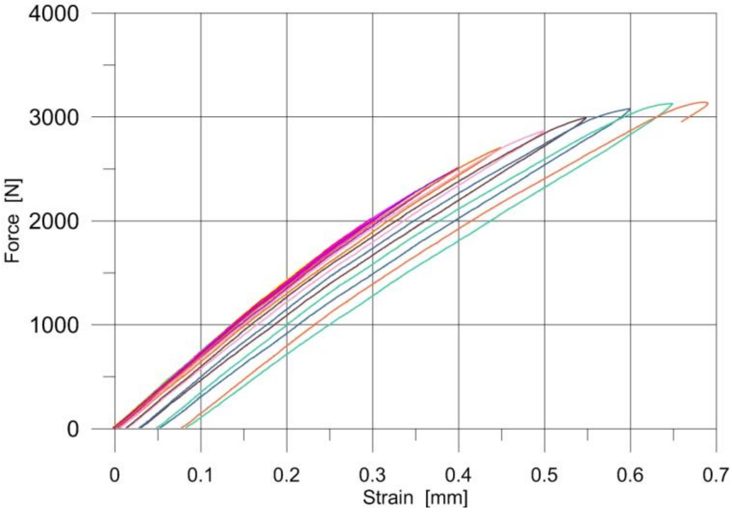

Fig. 1. Comparison of force vs. strain curves obtained for Gum Metal subsequent loading-unloading tension cycles at strain rate of $4x10^{-4}s^{-1}$ and step 0,002; 14 cycles have been performed until the specimen rupture.

The obtained mechanical characteristics confirm low elastic modulus and high strength of the Gum Metal. Mechanical and temperature relations for the 2nd, 8th and 14th cycles are shown in Fig. 2.

a)

b)

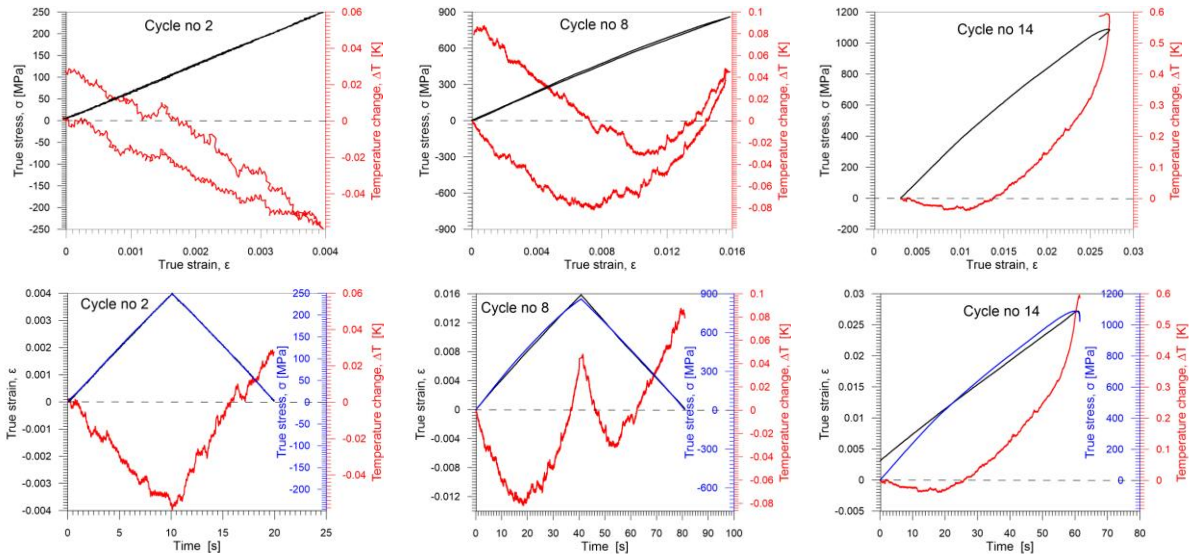

Fig. 2. Gum Metal cyclic tension loading at the strain rate of $4x10^{-4}s^{-1}$ with the step of 0,002: a) temperature change ΔT, stress σ vs. strain ε; b) temperature change ΔT, stress σ, strain ε vs. time.

Basing on the thermodynamic laws and Kelvin formula the specimen temperature linked to the deformation parameters one can determine a limit of the alloy reversible deformation. However in Fig. 2 a maximal drop in the specimen temperature occurs significantly earlier than the limit of the nonlinear reversible deformation [3, 4]. Thus such a large limit of reversible elastic deformation (super elasticity of Gum Metal) originates from other deformation mechanisms.

4. Concluding remarks

Thermomechanical behavior of Gum Metal under cyclic loading has been studied; 14 cycles have been performed until rupture of the specimen. The characteristics obtained during the test confirmed outstanding mechanical performance of Gum Metal but the thermal results are different from those of other Ti-, Al- alloys or steels and will be covered by our further thorougher research.

Acknowledgments

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5. References

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