# 3rd Polish Congress of Mechanics

# 21st International Conference on Computer Methods in Mechanics

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# Gum Metal – unique properties and results of initial investigation of the new titanium alloy

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Abstract

Initial results of effects of thermomechanical couplings in the β-Ti alloy, Gum Metal, subjected to tension are presented. An MTS testing machine allows obtaining stress-strain curves with high accuracy, while fast and sensitive infrared camera allows estimating temperature changes of the sample during the deformation process. The obtained mechanical characteristics confirm an ultra-low elastic modulus and high strength of the Gum Metal. The infrared measurements enable to indicate average or maximum temperature change accompanying the alloy deformation process, to estimate thermoelastic effect, related to the yield point in solids, whereas the temperature distribution on the sample surface enables to investigate localisation effects, leading to the sample necking and rupture.

*Keywords: Gum Metal, Titanium alloy, Elastic properties, Nonlinear elasticity, thermomechanical couplings, infrared camera*

## Introduction, results and discussion

The aim of the research is an investigation of the effects of thermomechanical couplings in new multifunctional titanium alloy, developed in Japan in the beginning of the 21st century, called Gum Metal, since it combines high elasticity and flexibility of rubber and strength of metal. It is a beta-type titanium alloy with a simple body-centered-cubic (bcc) crystal structure and composition fundamentally expressed as $Ti_3$ (Ta, Nb, V)+(Zr, Hf, 0); prepared by a powder sintering process.

Photograph of the experimental set-up designed for the Gum Metal tension test showing the MTS Testing Machine and Flir Co Phoenix Infrared System is presented in Fig. 1.

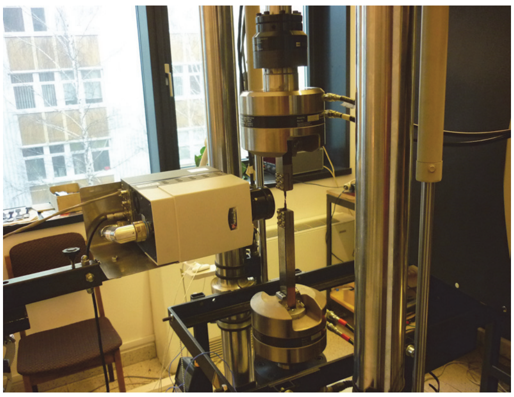

Figure 1: Photograph of the experimental set-up

The Gum Metal is characterized by an ultra-low elastic modulus with very high strength, superelastic nature - one digit higher in nonlinear elastic deformation (≈2.5%) compared to other metallic materials, super-plastic nature allowing cold plastic working without hardening up to (≈90%), very low linear coefficient of thermal expansion (similar to Invar) and a constant elastic modulus in the temperature range from -200 °C to +250 °C (similar to Einvar) [1,2,3,4]. A comparison of the mechanical curves obtained for Gum Metal and Steel during tension with strain rate $2x10^{-3}s^{-1}$ is presented in Fig. 2.

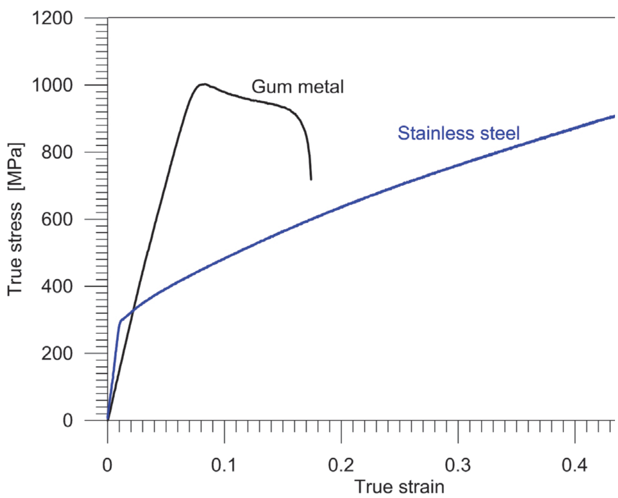


Figure 2: Comparison of stress vs. strain curves for Gum Metal and stainless steel - 316L up to the sample rupture

During the loading, the mechanical parameters and infrared radiation from the specimen surface were simultaneously recorded (Fig. 1). Stress-strain characteristics were found and the temperature changes of the specimens during the deformation process have been elaborated. The stress and the strain quantities were related to the current (instantaneous) values of the specimen cross-section values, obtaining so called true stress ( $\sigma_{true}$ ) and true strain ( $\varepsilon_{true}$ ) values, presented in the diagrams (Fig. 2, Fig. 4).

*The research has been carried out with the support of the Polish National Centre of Science under Grant No. 2014/13/B/ST8/04280. Authors are also grateful to Leszek Urbański and Maria Staszczak for obtaining mechanical data, elaborating diagrams and many useful experimental remarks.

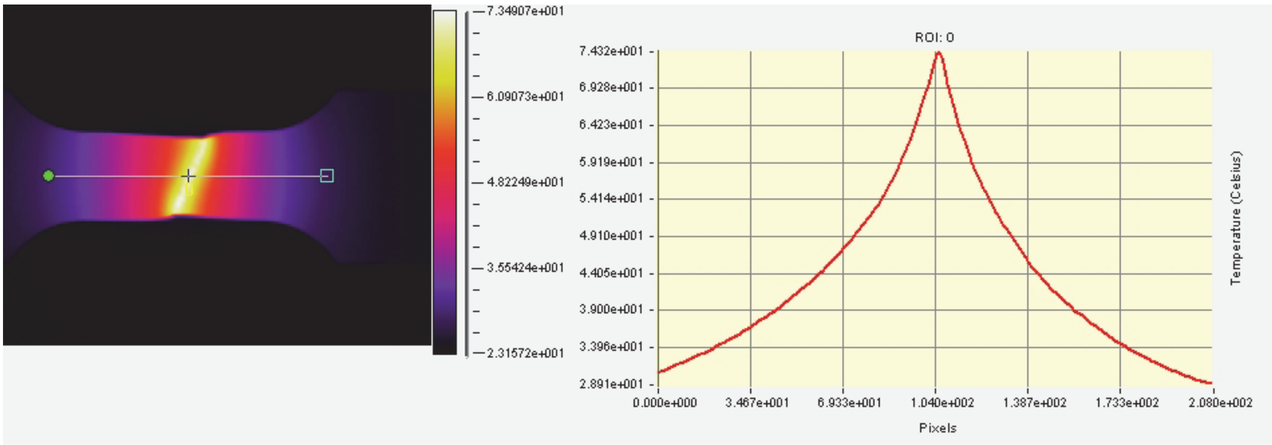


Figure 3: In left - temperature distribution on the Gum Metal sample during tension just before fracture; in right - the temperature change profile, indicated along the sample center denoted by a white line

The sample temperature distribution, called thermograms, are obtained in contactless manner by a fast and sensitive infrared camera; Fig. 1. An example of the temperature distributions on the Gum Metal specimen and the temperature profiles along the specimen center obtained for the tension test just before the specimen rupture are shown in Figure 3. A strong strain localization, characterized by a high temperature increase, was captured in the presented thermogram. Such thermograms and temperature profiles demonstrate a possibility to study a more advanced deformation process leading to the specimen necking and rupture. Moreover, a mean temperature during the deformation process has been calculated, using the infrared measurement methodology, elaborated in IPPT PAN for other materials [5]. The sample temperature referred to the deformation parameters allows indicating a limit of the alloy reversible deformation with high accuracy, according to the thermodynamic laws and Kelvin formula [6].

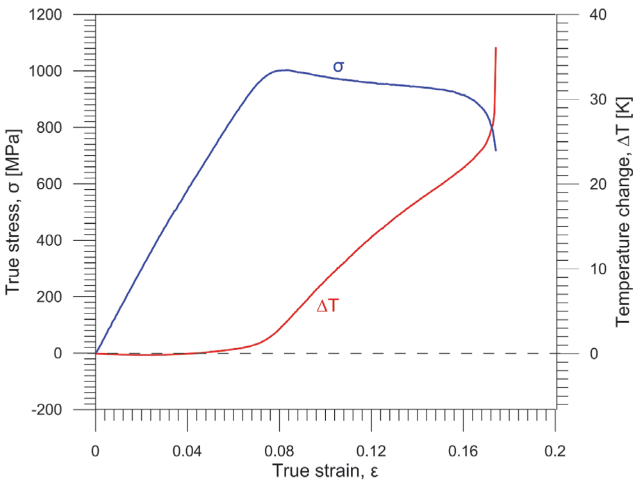


Figure 4: Stress and maximal temperature vs. strain of Gum Metal sample subjected to tension with strain rate $2x10^{-3}s^{-1}$

However, it can be noticed looking at Fig. 4 that a maximal drop in the Gum Metal specimen temperature occurs signify-cantly earlier than the limit of the reversible deformation, macroscopically estimated. It means that so large limit of the reversible elastic deformation (nonlinear) stressed as the Gum Metal "super" properties [1,2,3,4], follows from other deformation mechanisms and probably can not be described by the Lord Kelvin formula. The result is quite different from those observed until now for other titanium alloys, stainless steel and alumina.

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