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YIELDING AND STRAIN LOCALIZATION EFFECTS IN GUM METAL - A UNIQUE TI ALLOY -INVESTIGATED BY DIGITAL IMAGE CORRELATION AND INFRARED THERMOGRAPHY

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1. Introduction

The research concerns investigation of yielding and strain localization phenomena in a β-Ti alloy characterized by unique elastic-plastic properties, named Gum Metal [1,2]. Digital Image Correlation (DIC) and Infrared Thermography (IRT) were used [3]. The Gum Metal was subjected to tension on testing machine (TM) at three various strain rates up to rupture. Displacement and strain distributions were determined on the basis of DIC algorithm. The related temperature variations were found in contactless manner using IR camera. Mechanical and the corresponding thermal data were used to study large nonlinear reversible strain of the alloy.

2. Experimental results

The setup [Fig. 1] consists of MTS 858 TM and two cameras working in two different spectral ranges: visible (0.3-1 ηm) Manta G-125B and IR (3-5 ηm) ThermaCam Phoenix. Dog bone sample with sizes 100 x 8 x 0.5 mm were used, gauge part 7 x 4; length of virtual extensometer for DIC - 7 mm. More experimental data for investigation of effects of thermomechanical couplings in Gum Metal under tensile loading is presented in [3].

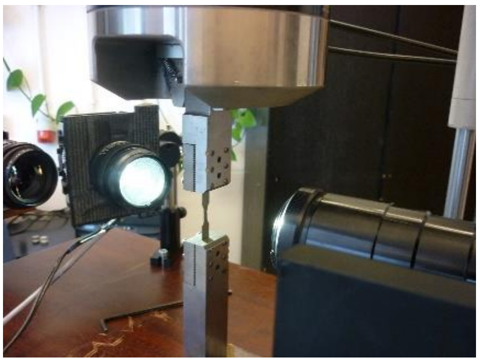

Fig. 1. Photograph of experimental set-up used for investigation of deformation and thermal fields

The stress σ and mean temperature changes (ΔT_{mean}) of the Gum Metal specimen vs. strain, obtained during tension at strain rate $10^{-2}s^{-1}$ up to strain 0.025, is shown in Fig. 2. The elastic yield limit, corresponding to maximal drop in the specimen temperature, and limit of mechanically reversible deformation, found in subsequent cyclic loading [3], are marked by A^* and B^*, respectively.

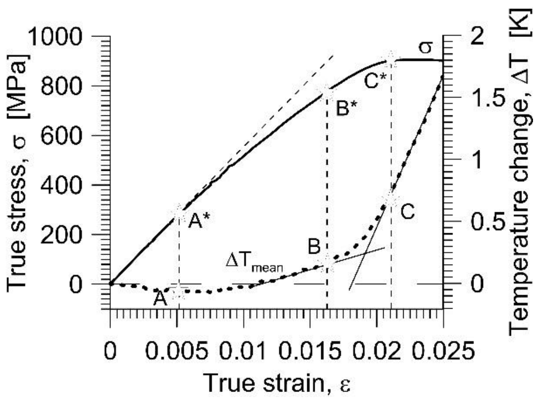

Fig. 2. Stress σ and temperature change (ΔT_{mean}) vs. strain ε obtained for Gum Metals tension up to 0.025

Increase in the specimen temperature (after it drops due to thermoelastic effect) started from point A revealed dissipative character of the process, probably caused by stress-induced phase transformation of ω or α'' phases [4]. Furthermore, small increase in the temperature in this range can be a sign that the transition takes place in small volume of the alloy, what is consistent with the results of microstructure analysis [4]. From the points B and C the slope of dependence ΔT vs. ε increases demonstrating that the deformation is irreversible from both thermodynamical and mechanical points of view. A clear tendency of the thermal plot to grow demonstrates exothermal nature of the governing deformation occurring in Gum Metal, also within the reversible strain range.

Stress strain curves derived by DIC for the Gum Metal tension at three strain rates till rupture, completed by the related temperature changes are presented in Figs 2 a, b and c. IR thermograms (left) and corresponding DIC distributions of the E_{yy} strain component (right) for the strain 0.07 (vertical dashed line in diagrams) are shown. Two kinds of the temperature of the gauge part of the specimen are analyzed: mean ΔT_{mean}, and maximal ΔT_{max}.

In the initial strain range the ΔT_{max} and ΔT_{mean} curves are overlapping; at the higher strains a gradually increasing discrepancy is observed. The point of the discrepancy (marked by a star) is an indicator of the onset of plastic strain localization. At strain rate $10^{-3}s^{-1}$, far from adiabatic conditions, no discrepancy is seen between the temperatures, yet the obtained non-uniform strain distribution demonstrates also the strain localization.

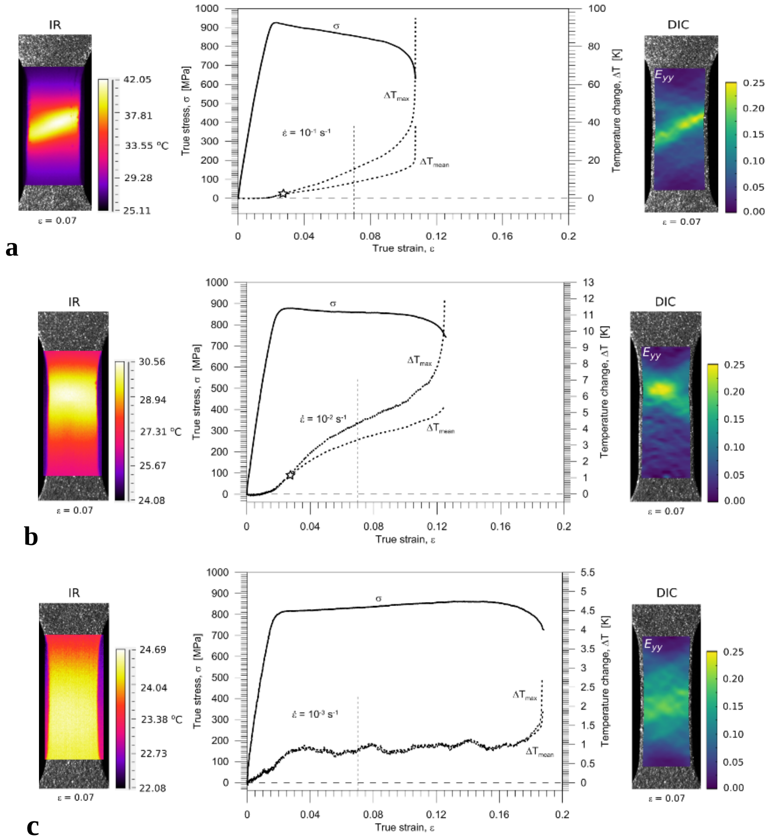

Fig. 2. Stress, maximal ΔT_{max} and mean ΔT_{mean} temperature vs. strain for strain rates: (a) $10^{-3}s^{-1}$, (b) $10^{-2}s^{-1}$, (c) $10^{-1}s^{-1}$

3. Conclusions

Large limit of Gum Metal reversible nonlinear deformation, underlined as the unique alloy "super property", originates from mechanisms dissipative nature; exothermic stress-induced transition of ω or α'' phases. During plastic deformation, both strain and temperature distributions demonstrate that at higher strain rates strain localization starts nucleating just after the yield limit.

Acknowledgements

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