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GUM METAL SUBJECTED TO COMPRESSION LOADING IN A WIDE SPECTRUM OF THE STRAIN RATES

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1. Introduction

Gum Metal stands for a group of multifunctional β-Ti alloys, which was developed by the Toyota Central Research and Development Laboratories at the beginning of the 21st century. Typical composition of Gum Metal Ti–36Nb–2Ta–3Zr–0.3O (in mass %), the fabrication process including cold working and the role of oxygen in the composition are critical for the unique mechanical performance of the alloy, i.e. low Young's modulus, large nonlinear recoverable deformation, and high strength [1]. The understanding of mechanical characteristics of the alloy subjected to loading at various strain rates is critical for its application in a variety of engineering solutions [2-4]. This work presents the behavior of Gum Metal in compression under quasi-static and dynamic loadings.

2. Methods

Mechanical behavior of the Gum Metal was investigated by conducting compression tests in a wide spectrum of strain rates, including impact loading: 10-3s-1 - 103s-1. An MTS testing machinewas used to measure the quasi-static behavior of the alloy (strain rates 10-3s-1 and 100s-1) under uniaxial compression. High strain rate uni-axial testing was performed using a Split Hopkinson Pressure Bar (SHPB) system (strain rates 940 s-1, 1460 s-1, and 2200 s-1). Microscopic evaluation was realized by using KEYENCE VHX-6000 digital microscope. Cross-sections of Gum Metal samples were metallographically ground and polished. To reveal the microstructure, the samples were etched with the use of Kroll's Reagent (20 ml H2O + 4 ml NHO3 + 1 ml HF).

3. Results and discussion

The obtained results of quasi-static and dynamic mechanical behavior of Gum Metal under compression at strain rates of 10^{-3} s^{-1}, 100 s^{-1}, 940 s^{-1}, 1460 s^{-1}, and 2200 s^{-1} are shown in Figure 1a. It can be noticed that Gum Metal is very sensitive to the strain rate applied during the compression loading. The rule the faster the stronger was confirmed.

Elastic-plastic transition during quasi-static compression appears at the stress level between 900 MPa and 1000 MPa. Almost no strain hardening is observed for the strain rate 10^{-3} s^{-1}. Slight strain softening is visible for the strain rate of 100 s^{-1}.At the significantly higher strain rates, the phenomenon of strain softening is present for each of the dynamic strain rates. During dynamic compression loading the peak flow stresses are on the order between 1200 MPa – 1400 MPa.

Optical microstructure of Gum Metal after Hopkinson test at the strain rate 2200 s^{-1} is presented in Figure 1b. In the micrograph the loading direction is vertical. It was noticed that equiaxed grains observed at the initial state are deformed after dynamic testing and are elongated in a direction perpendicular to the deformation direction. Fully developed adiabatic shear band (ASB) with the crack inside arose roughly at ~45° with respect to the loading direction indicating the maximum shear stress plane. Width of the shear band is near ~50 μm. Within the ASB structure composed of ultrafine equiaxed grains is observed. Such remarkable grain refinement had place since great temperature rise occurred during dynamic loading [5]. It can be also noticed that there is a temperature gradient athwart the adiabatic shear banding, leading to much refined grain size in the middle of ASB against ASB/matrix boundaries.

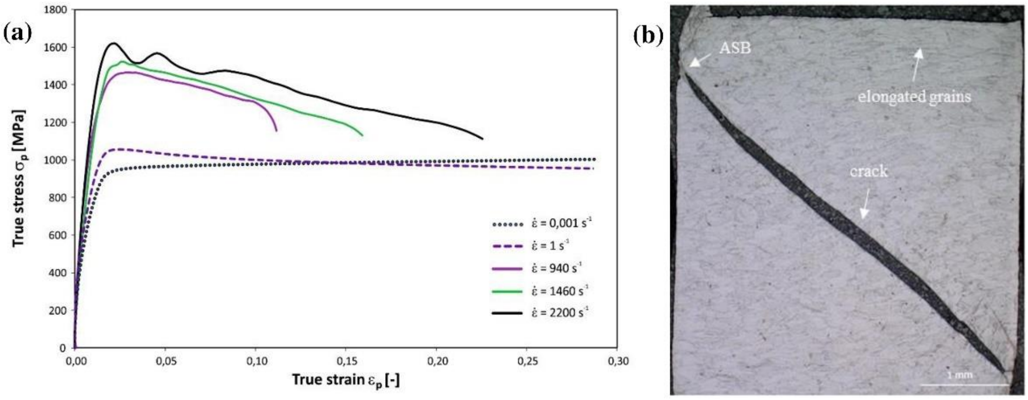

Fig. 1. a) Stress vs. strain curves of Gum Metal under compression at various strain rates; b) Optical micrograph of Gum Metal after dynamic loading at the strain rate 2200 s^{-1}

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4. References

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