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Unique mechanical performance of an innovative Ti-based superalloy Gum Metal under compression

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Gum Metal is an innovative Ti-based superalloy, which was developed in Toyota Central Central R&D Laboratories in 2003. Gum Metal has attracted increasing attention due to its exceptional properties, i.e. low elastic modulus, high strength, nonlinear elastic deformation and excellent cold workability with stable mechanical behavior over a wide range of temperature. Typical composition of Gum Metal is Ti–Nb–Ta–Zr–O. Its fabrication route includes powder metallurgy followed by solution treatment with cold working and enables production of big pieces. Thus, Gum Metal is successfully applied in many fields such as automotive, space, precision, robotic and sport equipment industries. The use of Gum Metal has led to development of a number of innovative solutions ranging from pressure sensors via golf club heads to spinal implant system.

In order to assure reliable application of Gum Metal to a variety of engineering problems, it is critical to get understanding of its mechanical characteristics under various loading conditions. The present research focuses on analysis of mechanical behavior of Gum Metal subjected to compressive cyclic loading. The polycrystalline Gum Metal rod with the composition near Ti–36Nb–2Ta–3Zr–0.3O in mass% was fabricated at Fukuoka University. It was cold-swaged and texturized in <110> direction. First, the structure of Gum Metal was analyzed by electron microscopy and X-ray diffractometry. Furthermore, elastic constants of the alloy were determined by ultrasonic tests. Subsequently, the cube specimens with sizes of near 2.85mm x 2.85mm x 3.55mm were machined and subjected to displacement controlled compression using the MTS 858 testing machine at the strain rate of 5x10-2s-1. The 10 loading-unloading cycles were conducted as follows; cycles 1 to 5 with a strain step equal to approximately 0.025 (true strain), 6 to 10 with a step of approximately 0.05. Additionally, during the deformation process the image sequences of the specimen surface were recorded. On the basis of the obtained sequences, the displacement and strain fields were determined using a DIC algorithm developed in IPPT.

The phase analysis reveals almost pure β-Ti phase with possible presence of ω-Ti precipitations. The structural observations confirm a strong texture in <110> direction and significant lattice rotations of grains in Gum Metal induced during the cold working process. Comparison of Young's moduli determined by ultrasonic tests in the swaging and the perpendicular directions implies an evident effect of the cold working on the mechanical properties of Gum Metal. The stress vs. strain curves confirm unique mechanical performance of the alloy: low Young's Modulus near 60 GPa and high strength over 1000 MPa. The curves profiles change significantly with each cycle and reveal distinct yield points; sharpened for the 4th and clearly observed for further cycles. Selected results of displacement and strain distributions at critical points of deformation obtained for the 10th cycle of the Gum Metal loading were analyzed.

In conclusion, selected results of mechanical behavior of Gum Metal compressed along the swaging direction during cyclic loading were presented. The unique mechanical performance of Gum Metal - low Young's Modulus and high strength were confirmed. During the cyclic loading the curves profiles change significantly with each cycle and reveal distinct yield points for the 4th and further cycles. Compression tests along perpendicular direction to the swaging one as well as modeling of the mechanical response of Gum Metal will be considered for our future research.

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