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ELASTIC AND PLASTIC ANISOTROPY OF GUM METAL INVESTIGATED BY ULTRASOUND MEASUREMENTS AND DIGITAL IMAGE CORRELATION

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1. INTRODUCTION

Recently, a class of metastable β-Ti alloys called Gum Metal has been drawing attention due to its unique mechanical performance and the related microstructural features as well as unconventional deformation mechanisms [1-3]. The research discusses the correlation between texture of Gum Metal induced during its fabrication by cold-swaging and its mechanical behaviour.

2. EXPERIMENTAL DETAILS

In this work, a Gum Metal rod with composition Ti–36Nb–2Ta–3Zr–0.3O (in mass %) with a significant texture induced by cold swaging with 90% reduction in area was supplied by Fukuoka University. The texture was confirmed by EBSD analysis. In order to study mechanical anisotropy of the alloy, elastic constants and Young's moduli in Gum Metal were determined by measurements of ultrasonic wave propagation pulse-echo method. Subsequently, Gum Metal cube samples with two orientations were subjected to compression to evaluate the mechanical anisotropy in relation to the loading direction versus cold swaging axis. During compression, two perpendicular walls of each sample were simultaneously monitored by two visible range cameras for further 2-dimensional DIC analysis [4], as shown in Fig. 1.

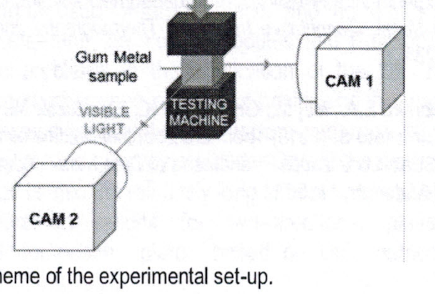

Fig. 1. Scheme of the experimental set-up.

3. RESULTS AND DISCUSSION

The pole figures presented in Fig. 2 clearly indicate a pronounced fiber <110> texture along the cold swaging axis, which is consistent with results for cold worked Gum Metal [1].

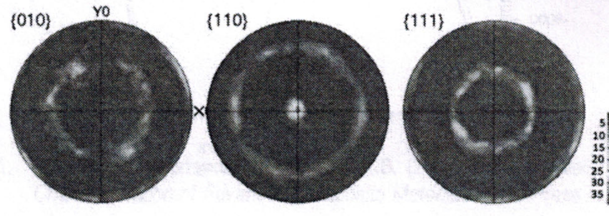

Fig. 2. Texture analysis of the Gum Metal sample; {0 1 0}, {1 1 0} and
{1 1 1} pole figures.

The elastic constants of the alloy were determined using Christoffel equations taking the measured ultrasonic velocities and assuming that the mass density of Gum Metal is equal to 5.6 g/cm^3. It should be underlined that all five elastic constants of polycrystalline Gum Metal were accurately and explicitly determined without the aid of any estimation technique. The obtained results are listed in Table 1.

Tab 1. Elastic constants of polycrystalline Gum Metal.

Elastic constant	C_{11}	C_{12}	C_{13}	C_{33}	C_{44}	$C_{66} = (C_{11}-C_{11})/2$
Value [GPa]	150.5	100.3	104.0	141.0	24.7	25.1

Based on the established elastic constants, the Young's moduli of the tested Gum Metal were calculated. The results obtained in parallel E_3 = 54.8 GPa and in a perpendicular direction

$E_{1/2}$ = 66.2 GPa to the cold-swaging axis 3 are of particular interest and they are listed in Table 2.

Tab. 2. Young's moduli of polycrystalline Gum Metal in relation to cold swaging axis.

Relation to cold swaging axis	Parallel	Perpendicular
Young's modulus [GPa]	54.8	66.2

Different values of the Young moduli in two perpendicular directions indicate considerable elastic anisotropy of Gum Metal.

Force vs. crosshead displacement curves for Gum Metal samples with two orientations under load-unload compression perpendicular (sample A) and parallel (sample B) to cold swaging axis are plotted in Fig. 3. Two points of an advanced plastic deformation P and Q were selected in the stress-strain graph.

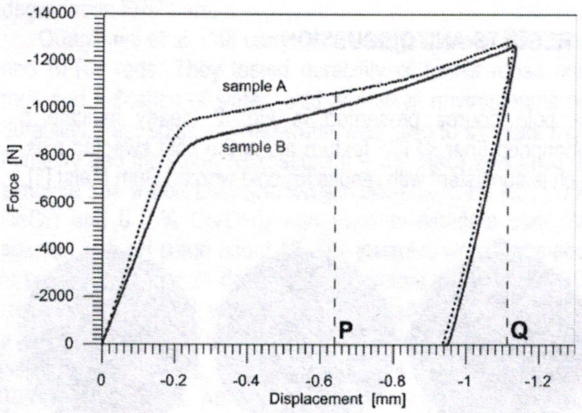

Fig. 3. Force vs. crosshead displacement curves for Gum Metal under compression perpendicular (dashed black line, sample A) and parallel (solid blue line, sample B) to cold swaging axis.

It is seen that in the case of Sample A compressed perpendicular to the swaging axis, the yielding occurs at higher force value in comparison to Sample B compressed parallel to the swaging axis.

The plastic anisotropy is seen at the fields of Hencky strain component (Hyy) determined in points P and Q by CAM1 and CAM2, shown in Fig. 4.

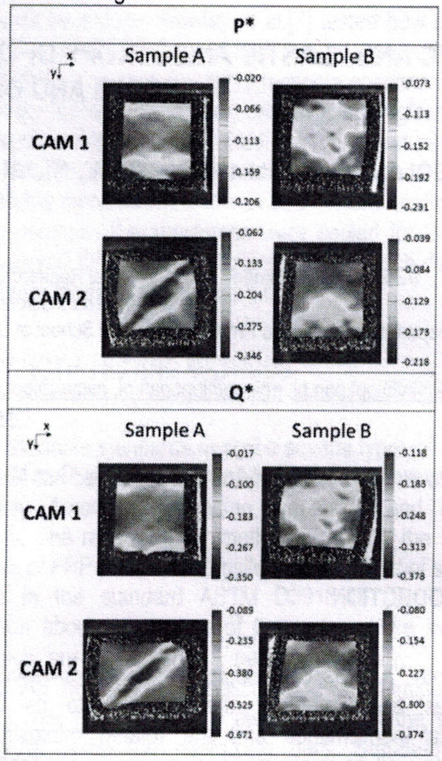

Fig. 4. Hencky strain component (Hyy) determined by DIC in points P and Q observed by two cameras CAM1 and CAM2.

In the case of sample A almost homogenous distribution of Hyy is observed for CAM1 and shear band formation for CAM 2. In the case of B sample the distribution of Hyy Hencky strain component for CAM1 is similar to that obtained for CAM 2 with the difference that the obtained distributions are reflected with respect to the horizontal axis of the sample. For the CAM1 the deformed zone is concentrated in the upper part of the sample, whereas for CAM 2 it is concentrated in its lower part.

Acknowledgements

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