In-situ synchrotron diffraction and self-consistent modelling used to determine plastic incompatibility stresses in textured AZ31 magnesium alloy

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A comprehensive study on the evolution of internal stresses in an extruded AZ31 magnesium alloy was conducted using energy-dispersive synchrotron X-ray diffraction (ED-XRD). The research evaluates both macroscopic (first-order) and intergranular (second-order) stresses that arise during uniaxial tensile deformation of a strongly fibre textured hexagonal close packed (hcp) material. Lattice strains were recorded for 16 sample orientations using nine crystallographic reflections [1].

An advanced q-parameter approach [2] was applied to separate the elastic lattice strain components related to the externally applied macroscopic load from those generated by grain-scale plastic incompatibilities caused by heterogeneous deformation. The findings demonstrate strong plastic anisotropy, premature yielding of favourably oriented grains, and significant development of intergranular stresses due to heterogeneous slip activity and twinning. Slip systems were classified into groups based on their similar roles in plastic deformation and grain-level stress evolution, which reduced the number of parameters necessary to describe the deformation mechanisms. In addition, combining Schmid factor analysis with stress distribution functions made it possible to identify the slip and twinning systems mainly responsible for the formation of second-order stresses associated with plastic incompatibility.

It was found, that under tensile loading, basal slip governs the evolution of plastic incompatibility stresses throughout deformation, initiating stress heterogeneity prior to macroscopic yielding [3]. With increasing strain, activation of non-basal ⟨a⟩ slip and twinning redistributes load toward harder grains associated with stable texture maxima. Under compressive loading, the twinning process initially reduces grain stresses, producing a plateau in the macroscopic stress-strain response. At later stages, plastic incompatibility stresses, governed by non-basal slip and the evolving twin orientations, cause the twins to become harder due to reorientation and progressively carry increasing load, resulting in material strain hardening.

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[1] G. Garcés, E. Oñorbe, P. Pérez, I.A. Denks, P. Adeva, Mater. Sci. Eng.: A 523 (2009) 21–26
[2] A. Baczmanski, P. Lipinski, A. Tidu, K. Wierzbanowski, B. Pathiraj, J. Appl. Crystal.. 41 (2008) 854–867.
[3] A. Baczmański, M. Wroński, P. Kot, S. Wroński, A. Łabaza, K. Wierzbanowski, A. Ludwik, M. Marciszko-Wiąckowska, Mater. Des. 202 (2021) 109543.