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ABSTRACT

Elasto-Plastic Material Behavior of Basal Textured Magnesium Alloys – Characterization and Modeling

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This study characterizes and models the three-dimensional anisotropic and asymmetric plastic behavior of hexagonal close-packed (HCP) basal textured wrought magnesium (Mg) alloys [1]. Twin-roll-cast Mg sheets are investigated, which typically exhibit a significant basal texture. Both experimental and numerical methods were employed. Uniaxial, pure shear, and equi-biaxial tests were conducted, accompanied by in-situ strain field measurements using digital image correlation (DIC). Strong strain localization was observed during uniaxial and equi-biaxial compression tests due to the formation of macroscopic bands of twinned grains (BTGs). Within the BTGs, the evolution of the lateral plastic strains exhibited strong anisotropy. For instance, the results of the uniaxial compression tests in rolling direction yielded plastic Poisson's ratios with respect to the transverse direction of about zero and with respect to the sheet normal direction of about one. In contrast, the uniaxial tensile tests result in a homogeneous strain field with almost isotropic material behavior.

Cyclic compression tests reveal that the strain localization persists and the initial macroscopic cracks always form within the BTGs [2]. For fatigue modeling, such as the concept of the highly strained volume presented in [2], it is essential to consider the stress-strain states exclusively within these localized areas. Hence, a multiaxial constitutive model was developed and implemented in the finite element method (FEM) software CalculiX via a user-defined material subroutine [3]. The model successfully represents anisotropic yield stresses, tension-compression asymmetry, pronounced strain localization, and anisotropy in lateral plastic strains. FEM simulations on uniaxial unnotched and notched compression specimens confirm the model's ability to accurately calculate the fatigue parameter for the concept of highly strained volume.

[1] Lou, X., Li, M., Boger, R., Agnew, S., Wagoner, R. (2007). Hardening evolution of AZ31 B Mg sheet. Int. J. Plast. 23, pp. 44–86. DOI: 10.1016/j.ijplas.2006.03.005

[2] Denk, J., Whitmore, L., Huber, O., Diwald, O., Saage, H. (2018). Concept of the highly strained volume for fatigue modeling of wrought magnesium alloys. Int. J. Fatigue 117, pp. 283-291. DOI: 10.1016/j.ijfatigue.2018.08.025

[3] Nischler, A., Denk, J., Mader, F., Whitmore, L., Saage, H., Prahl, U., Huber, O. (2024). Modelling the Elasto-Plastic Material Behavior of Textured Hexagonal Close-Packed Metals. In: Altenbach, H., Öchsner, A. (eds) State of the Art and Future Trends in Materials Modelling 2. Adv. Struct. Mater., vol 200. Springer, Cham, pp. 501-530. DOI: 10.1007/978-3-031-72900-3_23