



An experimental study of cyclic deformation of extruded AZ61A magnesium alloy

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ABSTRACT

Thin-walled tubular specimens were employed to study the cyclic deformation of extruded AZ61A magnesium alloy. Experiments were conducted under fully reversed strain-controlled tension–compression, torsion, and combined axial–torsion in ambient air. Mechanical twinning was found to significantly influence the inelastic deformation of the material. Cyclic hardening was observed at all the strain amplitudes under investigation. For tension–compression at strain amplitudes higher than 0.5%, the stress–strain hysteresis loop was asymmetric with a positive mean stress. This was associated with mechanical twinning in the compression phase and detwinning in the subsequent tension phase. Under cyclic torsion, the stress–strain hysteresis loops were symmetric although mechanical twinning was observed at high shear strain amplitudes. When the material was subjected to combined axial–torsion loading, the alternative occurrence of twinning and detwinning processes under axial stress resulted in asymmetric shear stress–shear strain hysteresis loops. Nonproportional hardening was not observed due to limited number of slip systems and the formation of mechanical twins. Microstructures after the stabilization of cyclic deformation were observed and the dominant mechanisms governing cyclic deformation were discussed. Existing cyclic plasticity models were discussed in light of their capabilities for modeling the observed cyclic deformation of the magnesium alloy.

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1. Introduction

With excellent properties such as low density, high specific strength, high damping capacity, and good recyclability, magnesium alloys have been increasingly applied to structural components in the automotive and aerospace industries to reduce fuel consumption and greenhouse gas emissions (Eliezer et al., 1998). The structural components in the transportation vehicles unavoidably experience cyclic loading, which results in fatigue failure. An understanding of cyclic deformation and fatigue is critical to the design and durability evaluation of engineering components.

Magnesium alloys have a hexagonal close packed (HCP) structure with very limited number of slip systems distributed asymmetrically over the crystallographic reference sphere. In order to satisfy the von Mises criterion which requires five independent deformation systems for an arbitrary homogeneous straining, various primary and secondary slip and twinning mechanisms have to be activated simultaneously (Graff et al., 2007). The relative prevalence of deformation mechanisms depends strongly upon the crystal orientation, temperature, and loading mode. The dominant slip system of magnesium at room temperature is slip in the close packed direction $\langle 11\bar{2}0 \rangle$ or $\langle a \rangle$ on the basal plane (Roberts, 1960). The critical resolved shear stress (CRSS) of basal slip in pure magnesium is approximately 0.5 MPa (Burke and Hibbard, 1952; Kelly

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