Understanding Twinning-Detwinning Behavior of Unalloyed Mg During Low-Cycle Fatigue Using High Energy X-ray Diffraction

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Abstract

It is well understood that twinning during deformation plays an important role in deformation of Mg and its alloys [1–8]. In hexagonal close packed (HCP) Mg alloys, the dominant deformation mode at room temperature is <a> slip on the basal (0001) plane Mg [9, 10]. The other slip systems—prismatic <a> slip, pyramidal <a> slip, and pyramidal <c + a> slip—require much higher stresses to activate during deformation [11]. Mechanical twinning allows for grains to easily deform along their c-axis [12] and has been the focus of significant, active research [e.g., 13–23].

Keywords

Low-cycle fatigue • Synchrotron diffraction • Magnesium

It is well understood that twinning during deformation plays an important role in deformation of Mg and its alloys [1–8]. In hexagonal close packed (HCP) Mg alloys, the dominant deformation mode at room temperature is <a> slip on the basal (0001) plane Mg [9, 10]. The other slip systems—prismatic <a> slip, pyramidal <a> slip, and pyramidal <c + a> slip—require much higher stresses to activate during deformation [11]. Mechanical twinning allows for grains to easily deform along their c-axis [12] and has been the focus of significant, active research [e.g., 13–23].

In unalloyed Mg and Mg alloys, with a c/a ratio less than the ideal value of 1.633, the $\{10\bar{1}2\}\langle 10\bar{1}1\rangle$ extension twinning is the dominant deformation mode, where extension along the c-axis can be accommodated, but not contractions along that same direction [16, 24]. As a result, during mechanical loading the tensile yield strength is significantly higher than the compressive yield strength resulting in a tension–compression asymmetry [25]. Begum et al., found that the tensile yield strength was much higher than the compressive yield strength during low-cycle fatigue (LCF) of an AM30 extruded Mg alloy and related this to twinning that occurs during compression and detwinning that occurs during tension [5]. During compression, twins form causing an 86.3° reorientation of the basal pole [9, 11, 15, 22]. During reversed unloading or tensile loading these twinned regions can undergo detwinning in which twins become narrower and/or disappear [11, 25, 26]. Detwinning causes a reorientation of the c-axis from the twin back to the matrix or parent grain [9, 25–27]. Twins can reappear upon reloading and thus, the twinning-detwinning behavior continues until the end of life [28].

In this study, the twinning detwinning behavior of extruded, polycrystalline unalloyed Mg under cyclic loading conditions was investigated at the Cornell High Energy Synchrotron Source (CHESS) using in-situ high energy X-ray diffraction. Measurements were conducted at three different strain amplitudes. The initial crystallographic texture was such that the c-axis in most grains was normal to the loading direction and therefore, favorable for extension twinning during compressive loading. The experimental results showed that an increase or decrease in the {0002} basal X-ray peak intensity was observed during low-cycle fatigue and these changes are indicative of the occurrence of twinning and

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detwinning. During cyclic loading complete twinning-detwinning occurred for the first few hundred cycles where all of the twins formed in compression were removed during tensile loading of the following cycle. Eventually, this phenomenon ceases and residual twins remain in the material throughout each cycle. At strain amplitudes below 0.5%, there was no indication of twinning during compressive loading. The complete article on this study can be found in the *International Journal of Fatigue* [29].

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