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Fatigue Modeling for Wrought Magnesium Alloys with the Method of Highly Strained Volume

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Abstract:

Wrought magnesium alloys provide a high lightweight potential because of their high weight specific static and fatigue strength and the possibility to design thin walled and large structures. In the field of transportation, where dynamic loading occurs, especially the cyclic fatigue be-havior of lightweight structures is important. To evaluate the fatigue lifetime for the range from low cycle fatigue to high cycle fatigue, a profound knowledge of the mechanical behavior and a proper fatigue modeling method are necessary.

In this study, the characterization of thin walled sheet metals consisting of the magnesium wrought alloy AZ31B and a proper fatigue modeling method are presented. The sheet metals were produced by twin roll casting and therefore have a strongly basal texture. This leads to strongly inhomogeneous strain distributions when exceeding the compression yield limit for in-plane loadings. The modeling of the fatigue lifetime is carried out with the novel method of highly strained volume.

The characterization of the fatigue behavior is carried out with the help of uniaxial cyclic tests on unnotched and notched specimens of different sizes and shapes and pure cyclic bending tests on unnotched specimens of different heights. In situ optical strain field measurements are conducted during the fatigue tests to investigate the elastoplastic deformation behavior. Before and after mechanical loading the microstructure was investigated by light microscopy and electron backscatter diffraction (EBSD) to take the local elastoplastic deformation behavior into account for fatigue modeling.

Wrought magnesium alloys show a specific deformation behavior which bases on the strongly basal texture and its twinning and detwinning behavior. The resulting mechanical properties are anisotropic and strongly asymmetric with respect to the yield limits and the strain hardening behavior in tension and compression. Both result from the formation of {10-12}-tension twins and the basal texture, where the c-axes of the hexagonal close packed lattice structure point approximately in normal direction of the sheet plane.

A strong localization of the plastic strain in form of macroscopic bands of twinned grains (BTG) occurs when a compressive loading within the sheet plane exceeds the yield limit. Within a BTG the measured strain is significantly higher compared to the adjacent regions, where no twinned grains are observed.

Therefore, there are different regions with different strains even at homogeneous stress distributions of an unnotched tension-compression bar. The position of the macroscopic crack initiation is always within the twinned and therefore highly strained regions of the specimens.

To consider all observed aspects in a fatigue model the method of highly strained volume was developed. Within this method the twinned highly strained regions are selected and evaluated. For lifetime prediction, the highly strained volume and a fatigue parameter are derived from the BTG and plotted over the number of cycles to failure in a three dimensional graph. As fatigue parameter the strain amplitude, the Smith-Watson-Topper parameter and an energy based fatigue parameter are used. The strain energy density is calculated with the help of a stress-strain-hysteresis model which is developed for variable strain amplitudes and mean val-ues. The consideration of all fatigue tests (different loadings, geometries and load ratios) by the method of highly strained volume with good modeling accuracy confirms the appropriate-ness of the method. The proposed method is expected to predict the lifetime for cyclic loaded arbitrarily shaped wrought magnesium structures based on known elastoplastic strain fields within the range from low cycle fatigue to medium cycle fatigue.

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