
MICROMECHANICAL MODELING AND EXPERIMENTAL ANALYSIS OF MAGNESIUM ALLOY WE43, FOR MEDICAL IMPLANT APPLICATIONS

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Abstract

INTRODUCTION

Bioresorbable materials are a critically important part of the next generation of medical implants, where the implant can degrade and resorb harmlessly into the body once it has completed its function (1). Bioresorbable metals, such as magnesium (Mg) alloys, hold great promise for cardiovascular and orthopaedic implant applications where tissue structural support of is needed while the tissue heals and recovers normal function. Mg alloys provide great structural support on implantation. However, they tend to have relatively high degradation rates in the bodily environment, resulting in the premature loss of structural support, and researchers have been actively exploring ways to retard degradation rates (2,3). The overall objective of this work is to develop micromechanical models of WE43 alloy capable of representing the mechanical performance and bioresorption (corrosion) behaviour of the material. The modelling methodology proposed here is novel and has not been achieved before.

MATERIALS AND METHODS

Magnesium alloys have distinct deformation behavior compared to other metals. This distinction stems from their hexagonal-close-packed (HCP) lattice structure (4). The micromechanical modeling utilizes crystal plasticity finite element (CPFE) modeling of the HCP crystal structure. The plastic deformation of a single crystal is assumed here to arise from crystalline slip and twinning. A UMAT subroutine is used to model the plastic deformation. In the first stage, a 2D unit cell model including 10 grains (Fig.1-a) was developed, and periodic boundary conditions were applied to this model. Experimental analysis in this study involves the use of 3D Diffraction Contrast Tomography (DCT), available using an in-house Zeiss Versa 620 system to determine typical grain size and shape statistics. The scanning images allow the construction of the CPFE models that will realistically represent the microstructure. DCT scans have been performed for samples with dimensions of $0.5 \times 0.5 \times 2$ mm that machined from different locations in a 50 mm-diameter extruded bar. For each sample, three sections at different lengths were individually modelled in 3D. Fig.1-b shows one section with dimensions of $0.304 \times 0.304 \times 0.304$ mm, containing 88 grains. NEPER is an open-source software that was used to generate tessellation corresponding to the polycrystal

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and to mesh it for FEM simulation (Fig.1-b). In this case, each grain has its own ID and specific crystallographic orientation.

RESULTS

Results for typical models in 2D Fig.1-a and 3D Fig.1-b are shown in Fig.1 for loading in tension, where the 3D models were generated from the DCT scan data as described above. The contours of strain provide valuable insights into the distribution and magnitude of strain across the entire sample.