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Study of Plastic-Yield Behavior of Trabecular Bone under Twisting and Bending Moment Stresses using a 3-D Microstructural Model

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ABSTRACT

Trabecular bone is a highly porous orthotropic material present inside human bones such as the femur and vertebra. The yield and failure properties of bones are of key interest in understanding and predicting bone fracture and bone implant systems. Trabecular bone experiences complex multiaxial loads which can lead to entire bone fracture. Knowledge of the failure properties of trabecular under multiaxial states of stress is quite limited especially under bending and twisting moment stresses. Analytical models of trabecular bone based on microstructural model can significantly enhance our standing of multiaxial failure behavior under such loadings. Microstructural models relying on homogenization approaches serve to relate deformation and failure mechanisms at the trabecular level to the macroscopic material behaviors, and thus provide a framework interpreting and extending experimental observations. For this purpose, Plastic yield surfaces are derived for lattice-like models of trabecular bone structure with relatively high effective density that failure occurs by fully plastic condition. The asymptotic discrete homogenization approach is involved to construct the plastic collapse surfaces of periodic 3D rod-like architecture of vertebral bone in couple stress space incorporating natural anisotropy of bone. Both in-plane and out-of-plane bending couple stress states in addition to torsional couple stresses are considered. A plastic yield criterion is adopted to address general bending and torsional couple loadings, accounting for combined cell wall bone microstructure bending and torsion interaction. The criterion is micromechanically motivated and relies on the calculation of the microscopic couple stresses (or micromoments) that are linked to the homogenized curvatures. The plastic yield surface is associated to a complete plastification of the trabecular strut section.

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