

XFEM Based Analysis and Optimization of Biomedical Materials and Structures for Fracture Criteria

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Abstract

Fracture is one of the most common failure modes in biomedical materials and structures, which in some scenarios could largely compromise the safety and longevity of the prostheses, thereby placing significant concerns in biomedical engineering and clinical societies. This study aims to develop a new computational procedure for analysis and design of implantable prosthetic devices under physiological conditions. The eXtended Finite Element Method (XFEM) technique is employed to model fracture initiation and propagation in the prostheses. It will first explore the fracture patterns for a number of biomedical scenarios, including (1) all ceramic dental materials (porcelain-zirconia system) (Zhang et al 2013, Ichim et al 2007), (2) fixed partial denture (FPD) and crown structures (Li et al 2004a and b), (3) ceramic tissue scaffolds, (4) femur – implant system for total hip replacement; and (5) arterial stents.

Following the fracture simulation and validation (e.g. Zhang et al 2013, Li et al 2004b), the Bidirectional Evolutionary Structural Optimization (BESO) procedure (Huang and Xie 2010), is implemented within in the XFEM framework for topology optimization by suppressing fracture incidence and minimizing peak tensile stress to strength ratio of the structure (Li et al 2001). A series of biomedical examples are presented for topology optimization with or without pre-cracks.

The study demonstrated the effectiveness of XFEM for fracture analysis and design optimization in a range of biomedical materials and structures. XFEM combined with BESO may be of potential to predict and enhance the safety and longevity of prosthetic devices in other biomedical scenarios.

Keywords: XFEM, Fracture, Biomaterials, Prosthesis, Topology optimization

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