Fracture simulation of Co-continuous composite materials under static loading

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ABSTRACT

Co-continuous composites consist of two materials with very different properties that can be fine-tuned to give high strength, stiffness, energy dissipation, impact resistance, and toughness. The geometry of these composites can be developed using triply periodic minimal surfaces, which can be described mathematically by level-set functions [1]. This geometry allows each of the two interleaved materials to form a lattice, which can repeat itself continuously in three-dimensional (3D) space. This highly structured geometry makes co-continuous materials suitable for 3D printing. Tailoring such composite materials to give high fracture toughness and energy dissipation can make them useful for extreme condition applications like shielding of military vehicles and aircraft. This study attempts to study the fracture behavior of three different co-continuous structures under static loading using Extended Finite Element Method (XFEM) combined with Cohesive Zone Modeling (CZM) approach. The simulation results are compared with experiments on 3D printed composite models. The benefit of using XFEM approach for fracture simulations is that it allows the visualization of crack growth along an arbitrary, solution dependent path without the need to remesh the model after each crack growth increment. This means that there is no need to predefine the crack path and the computational time is small compared to fracture mechanics using classical finite element approach.

The three structures in this simulation are simple cubic, body-centered cubic, and face-centered cubic. The two phases in the co-continuous composite are: a glassy polymer and a rubbery elastomer. The glassy polymer is modeled as an elastic-viscoplastic material and the rubbery elastomer is modeled as a neo-Hookean material. Simulation results show that a large number of cracks initiated and propagated within the glassy polymer phase but were restricted from growing further by the rubbery elastomer phase. Different microstructure materials show different failure behavior. The crack formation and propagation is highly 3D which indicates that only surface observation cannot give a comprehensive understanding of the material failure. The combined XFEM and CZM provide a more fundamental understanding of the failure mechanism of the investigated 3D co-continuous materials. Some further work is proposed based on the current study.

REFERENCE