acture Analysis on Ferroelectrics using a Micromechanical Model Embedded onto Scaled Boundary Finite Element Method

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Abstract

Piezoelectric material-based devices play a vital role in sensing and actuation applications in many engineering fields. The electromechanically coupled ferroelectric polycrystalline material exhibits complex nonlinear behavior under higher magnitudes of mechanical and electrical loading. The presence of minor cracks in the polycrystalline piezoelectric material influences the localized electric fields and mechanical stresses. The solution for stress at the singularity point is realized through the implementation of the scaled boundary finite element method (SBFEM). A micromechanical model combined with the SBFEM approach explores the domain switching near the crack tip for the cyclic electric field and different compressive stresses at the grain level. In comparison, the nodal solution at the boundary and scaling center of the Voronoi polygon relates to the state of grain in the polycrystalline material. The Griffith theory for brittle material is employed to compute the permissible stress value for a given crack size.

The Griffith's energy-based theory finds the fracture stress for initiated crack length in brittle natured piezo-ceramics, declaring if the crack is stable or unstable for the applied electromechanical loading condition. The evaluation of fracture mechanics is essential in predicting material reliability. For numerical analysis, the new crack tip location is identified through dynamic crack propagation analysis based on the stress intensity factor, crack tip velocity, and the crack angle. In the novel re-meshing technique, the boundary of the crack element is scaled down at the existing crack tip using a minimal scaling factor value and transformed to a new crack tip position. The electric field near the crack tip of the material causes the domain switching effect and its stress singularities. A negative electric field with externally applied tensile stress contributes to crack growth more suddenly than a positive electric field acting on them. On crossing the material fracture toughness, the crack propagates to grow across the material. The simulation results carried out based on the proposed work follows the experimental observation performed through compact tension tests elsewhere.