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NUMERICAL ANALYSIS OF FRACTURE OF PRE-STRESSED FERROELECTRIC ACTUATOR TAKING INTO ACCOUNT COHESIVE ZONE FOR DAMAGE ACCUMULATION

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Summary: Operational safety of smart-structures as well as ferroelectric multilayer actuators is essentially reduced by crack formation. Such failure processes are numerically simulated in the current research by finite element method (FEM) employing a coupled electro-mechanical 3D analyses.
At first, the poling process during manufacturing the actuator is simulated.
After the end of the poling process, an alternating electric loading of a constant amplitude is applied.
In order to model the bulk material behavior, ferroelectric user elements are implemented into the commercial software ABAQUS, thus allowing to simulate poling process of the actuator as a result of the micromechanical domain switching. Material damage is accumulated in accordance with a traction-separation law (TSL) of an electro-mechanical cyclic cohesive zone model (EMCCZM).
The cohesive zone technique enables to capture initiation and accumulation of damage, while domain switching modeling provides the realistic simulation of the non-linear processes occurring in the ferroelectric material.
In the cohesive zone, a finite electric permittivity is considered, which degrades with damage accumulation. Another important feature is that applied cyclic loading of a constant amplitude leads to increasing damage which can not be modeled with a monotonous TSL.
The results of the numerical simulation qualitatively coincide with the experimentally observed patterns of crack initiation.
It was found that the poling process of ceramics may induce cracking at an electrode surface which is further developed by the pure electric cyclic loading. Damage evolution until failure is observed due to mechanical and electrical field concentrations near the electrode tip. The influence of the CCZM parameters and the value of an applied electric potential difference on the fracture resistance of the actuator are analyzed.
To the authors' knowledge, it is the first analysis dealing with a coupled ferroelectromechanical modeling combined with damage accumulation in smart structures. Such simulation enables future optimization of the actutators design.