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MECHANICAL DEGRADATION AND LIFETIME PREDICTION OF TETRAGONAL FERROELECTRICS UNDER CYCLIC ELECTROMECHANICAL LOADING

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Summary: Ferroelectric materials, such as barium titanate, are widely used in smart structures and devices as actuators, sensors etc. To investigate the material behavior, a condensed model for ferroelectric solids with tetragonal unit cells is presented. The approach is microelectromechanically and physically motivated, considering discrete switching processes on the level of unit cells and quasi-continuous evolution of inelastic fields on the domain wall level. To calculate multiple grain interactions, an averaging technique is applied [1,2]. Hysteresis loops are simulated for a pure electric and an electromechanical loading to demonstrate the influence of a compression preload on the poling and stress-strain behavior. Further, residual stresses are calculated as a result of switching processes and interaction between crystallits. To study the high cycle fatigue damage and to predict lifetime of ferroelectric devices, an accumulation model is proposed based on the growth of microcracks [2]. Here, the Paris law [3] is applied to calculate fatigue crack growth rates. The lifetime is calculated considering different parameters, e.g. initial micro crack lengths, material parameters, loading cases etc. The simulations agree with experimental findings, where actuation efficiency and structural integrity come out to be opposing properties.

References

[1] S. Lange, A. Ricoeur, A condensed microelectromechanical approach for modeling tetragonal ferroelectrics, Int. J. Solids Strut., 2014, http://dx.doi.org/10.1016/j.ijsolstr.2014.11.004.
[2] S. Lange, A. Ricoeur, A condensed microelectromechanical constitutive and damage model for tetragonal ferroelectrics, Proceedings in Applied Mathematics and Mechanics, in press, 2014.
[3] P. Paris, F. Erdogan, A critical analysis of crack propagation laws, J. Basic Eng. 85 (1963), 528-534.