Multiscale Simulation of Piezoelectric Materials using FE^2 Methods and Configurational Forces

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Abstract. Multiscale Simulation has become increasingly important in determining the macroscopic material response and in capturing the evolution of the microstructure of inhomogeneous materials, e.g., piezoelectric materials. In this work, two-scale classical (first-order) homogenization of an electro-mechanically coupled material using a FE^2-approach is discussed. A new set of boundary conditions for the mechanical part of the material is presented in order to solve the boundary value problem (BVP) on the micro level. These boundary conditions helps us to determine consistent configurational forces on the macro level. The homogenized coefficients of the elastic, piezoelectric and dielectric tensors for small strain are explicitly formulated, as well as the homogenized remanent strain and remanent polarization [1, 2]. Different representative volume elements (RVEs) are used to capture the domain microstructure of the piezoelectric material. Two different schemes are considered: in the first case, domain wall movement is not allowed; in the second case, the movement of the domain walls is taken into account using a domain wall kinetics based on configurational forces on the domain walls [4]. Based on the multiscale model and the homogenized configurational force [3], the mode-I crack problem in piezoelectric material is simulated. The effect of the applied electric field on configurational forces at the crack tip has been extensively investigated. The configurational force at the crack tip is lower in the case of an evolving microstructure than that of a fixed microstructure. Moreover, with the help of the multiscale simulation, the hysteresis loops of piezoelectric material are recapitulated on the macro level.

References

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