

Nonlinear Electro-mechanical Responses of Ferroelectric Ceramics and Active Composites

Anastasia H. Muliana, Amir Sohrabi, and Vahid Tajeddini
Department of Mechanical Engineering, Texas A&M University
amuliana@tamu.edu

Ferroelectric ceramics, such as lead zirconate titanate (PZT) and barium titanate (BaTiO_3), exhibit nonlinear electro-mechanical responses when they are subjected to high mechanical and/or electric field inputs. These materials also show hysteretic polarization and butterfly strain responses when they are subjected to a cyclic electric field input with high amplitude, in which the materials experience polarization switching. A phenomenological constitutive model for rate-dependent electro-mechanical responses, including polarization switching is considered in order to examine the effect of frequencies on the overall performance of ferroelectric ceramics. The electro-mechanical coupling constants are taken as functions of a polarization state and in absence of polarization the electro-mechanical coupling constants would vanish. Ferroelectric ceramics are inherently brittle, which limit their applications to small deformations. In order to develop a relatively compliant material with high electro-mechanical coupling effects, ferroelectric ceramics of various shapes and sizes are often dispersed in ductile matrix, such as metals and polymers, which form electro-active composites. This study also presents modeling the overall nonlinear and hysteretic responses of active composites comprising of ferroelectric ceramics (active constituent) and inactive constituent. The development of electro-active materials offers a great potential for advancing structural health monitoring techniques, stealth and morphing aircrafts, and deployable structures. The electro-mechanical constitutive models are implemented in finite element (FE) and used to analyze the shape-changing performance of various active structures comprising of ferroelectric constituents. Desired shape configurations can be achieved in principle by selecting appropriate values for the electric field inputs at different locations. The presented numerical analyses can be used for preliminary design of electro-active systems controlled by mechanical and non-mechanical stimuli.