Nonlinear electro-elasticity for piezoelectric materials and structures using a multiplicative decomposition of the deformation gradient

Alexander Humer*, Elisabeth Staudigl† and Michael Krommer†

*Institute of Technical Mechanics
Johannes Kepler University Linz
Altenberger Str. 69, A-4040 Linz, Austria
e-mail: alexander.humer@jku.at, web page: http://www.jku.at/tmech

†Research group - Mechanics of Solids
Institute for Mechanics and Mechatronics, TU Wien
Getreidemarkt 9, A-1060 Vienna, Austria
e-mails: {elisabeth.staudigl,michael.krommer}@tuwien.ac.at
web page: http://www.mec.tuwien.ac.at/research/mechanics_of_solids/EN/

ABSTRACT

Nonlinear modelling of the inelastic behaviour of materials by a multiplicative decomposition of the deformation gradient tensor is common for finite strain problems. Among the various fields of finite strain problems, this concept has proven applicable in thermoelasticity, elastoplasticity, as well as for the description of residual stresses arising in growth processes of biological tissues [1]. In the context of advanced materials, electro-elastic elastomers have been investigated in [2], shape-memory alloys in [3] and piezoelectric materials in [4], in which reversible piezoelectric processes were considered within a three-dimensional continuum theory. With respect to nonlinear piezoelectricity, we extend our previous work on three-dimensional continua [4] to account for electrostatic forces by means of the concept of the total stress tensor.

Moreover, we translate this formulation to thin piezoelectric plates in the present paper. We model such plates as material surfaces, for which material points have translational and rotational degrees of freedom; the latter are further constrained to the case, for which transverse shear is negligible. On the structural level two strain measures, which account for the changes of the first and second metric tensor of the material surface. In extension to the three-dimensional case, a hybrid, multiplicative/additive decomposition is proposed for the plate.

The constitutive relations are linearized to find the well-known Voigt’s theory of piezoelectricity. Some numerical examples comparing the results from the shell theory to three-dimensional results verify the proposed formulation for thin piezoelectric shells.

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REFERENCES


