Teaching Seminar by:

Prof. A. Menzel
Institute of Mechanics, TU Dortmund, Germany.
Division of Solid Mechanics, Lund University, Sweden.

Modelling and simulation of electromechanical coupling – application to piezoceramics and electro-elastic polymers.

24th May, 10am-13:30pm. Room: B2-106

Material possessing electromechanical coupling phenomena are a prominent group within the class of smart materials. Such materials can transform electrical energy into mechanical energy and, possibly, vise versa. These properties make materials with electromechanical coupling phenomena very attractive for the design of smart devices, such as sensors and actuators. Two typical examples are piezoceramics, which undergo states of small deformation, and electro-active polymers, which may exhibit states of finite deformation.

The first part of the lectures introduces the general modelling of electromechanical coupling phenomena from a continuum mechanics perspective. This includes in particular relevant balance relations. Special emphasis shall then be placed on the modelling of piezoceramics under state of small strains. Since such materials show hysteresis behaviour under sufficiently high levels of electromechanical loading, a set of suitable internal variables is introduced together with related evolution equations. The modelling framework is embedded into an electromechanically coupled finite element formulation in order to simulate representative boundary value problems under inhomogeneous states of deformation.

The second part of the lectures addresses the modelling of electro-active polymers under states of large strains. Even though such polymers in general show viscous response, the lecture shall restrict to the modelling purely electro-elastic behaviour. One the one hand, different particularisations of a phenomenological framework are discussed, whereas a so-called micro-sphere model is elaborated on the other. This micro-sphere framework may transform statistical physics based constitutive models to a macroscopic continuum framework. Both approaches are embedded into an electromechanically coupled finite element formulation.

The third part of the lectures focuses on the algorithmic implementation of finite deformation electro-elasticity under homogeneous states of deformation. The general framework can be interpreted as an iterative constitutive driver - including tangent operators similar to those required for finite element formulations. Special emphasis shall be placed on incompressibility, different phenomenological models, a simple micro-sphere application and stability phenomena.

A. Menzel, A. Arockiarajan, and S.M. Sivakumar. Two models to simulate rate--dependent domain switching effects - application to ferroelastic polycrystalline ceramics. Smart Mater. Struct., 17:015026, 2008.

K. Jayabal, A. Menzel, A. Arockiarajan, and S.M. Srinivasan. Micromechanical modelling of switching phenomena in polycrystalline piezoceramics. Comput. Mech., 48:421-435, 2011.

S. Maniprakash, R. Jayendiran, A. Menzel, and A. Arockiarajan. Experimental investigation, modelling and simulation of rate-dependent response of 1-3 ferroelectric composites. Mech. Mat., 94:91-105, 2016.

A. Ask, A. Menzel, and M. Ristinmaa. Modelling of viscoelastic dielectric elastomers with deformation dependent electric properties. Proc. IUTAM, 12:134-144, 2015.

S. Thylander, A. Menzel, and M. Ristinmaa. An electromechanically coupled micro-sphere framework - pplication to the finite element analysis of electrostrictive polymers. Smart Mater. Struct., 21:094008, 2012.