

Generalised Continua, Electromechanical Coupling and Scale Effects

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Abstract

Generalised continua are characterised by extra degrees of freedom or incorporate higher gradients of the degrees of freedom and naturally exhibit one or multiple internal length scales and allow for non-classical loading such as moments to apply. Scale effects are relevant when the dimensions of the specimen or structure themselves are in the micron and submicron scale, but also when it comes to high strain concentrations as in the case of localised shear bands or at crack tips etc. However, the formulation of inelastic generalised continua is not straightforward due to the very fact that such continua do exhibit more than one strain measure. In addition, the numerics of extra degrees of freedom, e.g. the rotations, can be a delicate matter as well. In the first part of the paper a unified framework for elastic and inelastic generalised continua is presented. New formulations for such continua and deformations are considered including whole numerical frameworks and examples.

Furthermore we consider new formulations for electro-active polymers (EAP) which recently attracted much interest. Upon electrical loading, EAP exhibit a large amount of deformation while sustaining large forces. The electromechanical coupling formulation is embedded in the generalised framework mentioned above. Here, we adopt a strain gradient approach and extend it to encompass the electromechanically coupled behaviour of EAP. A new aspect of the electromechanical formulation relates to the multiplicative decomposition of the deformation gradient, well known from plasticity, into a purely elastic part and a further part which relates to the electric field. The formulation is elegant, makes for clarity and is numerically efficient. Further numerical examples of coupled large deformations are presented as well.

References

- [1] C. Sansour (1998). A unified concept of elastic-viscoplastic Cosserat and micromorphic continua. *Journal de Physique IV Proceedings* 8, 341-348.
- [2] C. Sansour and S. Skatulla (2009). A strain gradient generalised continuum approach for modelling elastic scale-effects, *Comp. Meth. Appl. Mech. Engrg.* 198, 1401-1412.
- [3] S. Skatulla, A. Arockiarajan, C. Sansour (2009). A nonlinear generalized continuum approach for electro-elasticity including scale effects, *Journal Mechanics and Physics of Solids* 57, 137-160

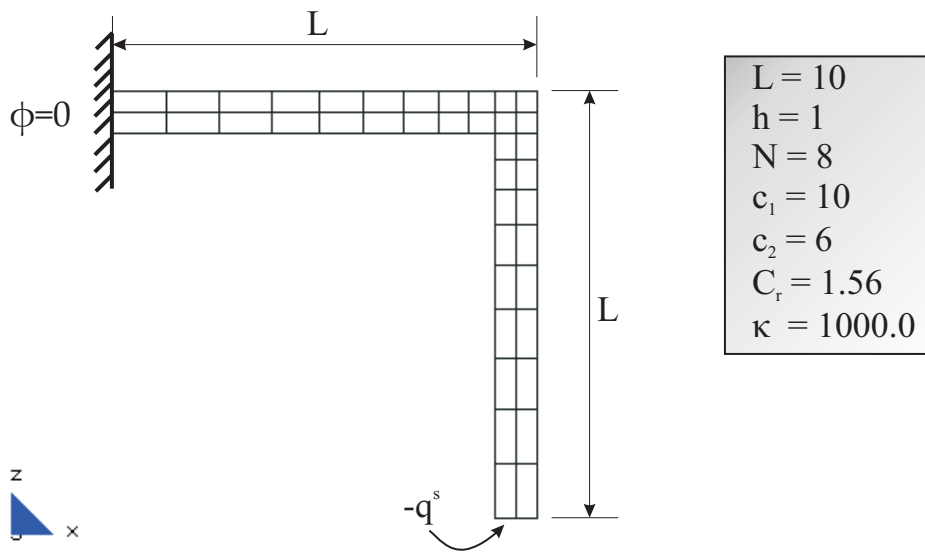


Figure 1: Problem configuration

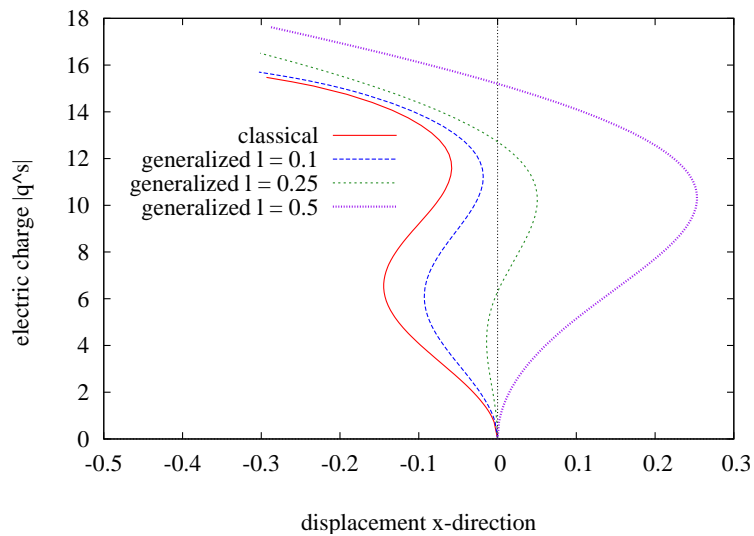


Figure 2: Electric surface charge versus displacement at the tip of the beam in x-direction simulating the generalised approach based on a one-dimensional microspace using as micro-director $\mathbf{a} = \mathbf{x}_{,x}$ with different magnitudes for the internal length scale parameter l_x