Abstract

Enrichment of constitutive models of hyperelasticity including material rheological properties

The thesis proposes an enrichement of the constitutive relations of the hyperelastic models of compressible and slightly compressible materials with a description that allows energy disspiation to be modelled, taking into account the postulates of the PhD thesis. The basis for this generalisation is an enriched Ciarlet model of a polyconvex stored energy function (SEF). In the case of the slightly compressible material models, the SEF function associated with isochoric deformations relates to the Ishihara-Zahorski model, which is a consistent second-order expansion with respect to the norm of the isochoric right Cauchy-Green deformation tensor. Under the assumption of incompressibility, the function in this form also satisfies the existence theorem for the solution of the hyperelasticity boundary-value problem. The parameters of both models are defined such that, as a result of the quadratic approximation of the ES function with respect to the Lagrange strain tensor, they are clearly related by the shear modulus μ_0 and the volume compressibility modulus K_0.

The first proposal to generalise the constitutive relations of hyperelastic models of description of viscous properties is to introduce an internal variable in the form of a scalar variable similarly to the constitutive relations of material models in the framework of continnum damage mechanics (CDM). In addition to modelling damage phenomena, the constitutive relations within the presented framework provide description of rate-dependent materials as well as creep and relaxation phenomena.

The second proposal is to introduce an internal variable in the Helmholtz function in the form of a second-order tensor. The form of the evolution equation for such an internal variable reduces the model to the integral form of the visco-elastic QLV known in the literature. In terms of this class, it is possible to model the rate-depentent behaviour and permanent deformations in the results of the load-unload process.

Both classes of models for compressible materials have been extended in the framework of the description of fibre-reinforced materials. Consequently, the constitutive relation of such a model can have the interpretation of a composite material consisting of a visco-elastic matrix and elastic fibres. The focus of this work is on a model with a single family of fibres, which gives a sense of a simplified version of the material with transversal isotropy.

The visco-hyperelasticity constitutive relations proposed in the work are implemented in the Abaqus software using UMAT and UANISOHYPER interfaces. Based on these subroutines, verification calculations are performed in example boundary-value problems with homogeneous as well as inhomogeneous deformation fields.

Keywords: hyperelasticity, visco-hyperelasticity, elastic energy, dissipation, transverse isotropy, finite element method, fibre-reinforced materials