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Multi-scale modelling of arterial tissue: linking networks of fibres to continua

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Abstract

In this work we develop a multi-scale model to characterise the large scale constitutive behaviour of a material featuring a small scale fibre architecture. The Method of Multi-scale Virtual Power (MMVP) is employed to construct the model. At the macro-scale, a classical continuum mechanics problem is formulated in the finite strain regime. At the micro-scale, a network of fibres, modelled as one-dimensional continua, composes the representative volume element (RVE). The MMVP provides a full characterisation of the equilibrium problem at the RVE, with consistent boundary conditions, as well as the homogenisation formula which defines the first Piola-Kirchhoff stress tensor. Particular attention is given to the fact that the macro-scale continuum could be considered incompressible. Numerical experiments are presented and model consistency is verified against well-known phenomenological constitutive equations. Scenarios departing from the hypotheses of such phenomenological material models are discussed.

Keywords: Multi-scale modelling, Fibre network, Representative volume element, Biological tissues, Virtual power, Non-affinity

1. Introduction

Constitutive modelling of arterial tissue is a core subject towards the rationally modelling of complex mechanical processes related to the onset