A micromorphic-fibre continuum approach applied to patient-specific modelling of the heart

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ABSTRACT

Cardiovascular diseases are among the most common causes of death in the world. Computational modelling in combination with medical imaging techniques, mechanical tissue testing, as well as cell and molecular biological analysis has the potential to help better understanding the underlying physiological mechanisms of heart failure and guide decision making in finding patient-specific treatment options in the future.

In this contribution we want to focus on the highly heterogeneous, anisotropic and non-uniform myocardial material composition (LeGrice et al. 1995). In the past it has been discovered that the initially crimped and coiled collagen fibres straighten during passive filling (Robinson et al. 1988) and that loosely interconnected sheets are able to slide over one another (LeGrice et al. 1995). In contrast to classical models of phenomenological nature, e.g. (Holzapfel and Ogden 2009), this work proposes a micromorphic continuum-based formulation which features extra degrees of freedom and corresponding strain and stress measures. The approach can therefore account for the hierarchical fibrous characteristics of the myocardium which are associated with micro-structural deformation of muscle-fibre bundles as well as their motion relative to the bulk material. As such, the assumed hyperelastic material behaviour of myocardial tissue is represented by a non-linear strain energy function which includes contributions linked to the bulk material representing the cytoskeleton and the micromorphic-fibre continuum emulating the micro-kinematics of the interwoven muscle-fibre bundles.

A computational case study illustrates the approach simulating the biomechanics of a patient-specific left ventricle during diastolic filling.

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