Cardiac tissue mechanics with fibres modelled as one-dimensional Cosserat continua

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Classically, the elastic behaviour of biological tissues is modelled using anisotropic strain energy functions which are supposed to capture the averaged behaviour of the matrix and the fibres. The strain energy function can be derived via representation theorems for anisotropic functions. Alternatively, a superimposed continuum approach can be adopted where the matrix is considered as an isotropic material but the fibres are taken as superimposed one-dimensional continua. The latter approach allows for the inclusion of any number of families of fibres. In either case the state of stress in the fibres is one-dimensional and is parallel to the fibre tangent. Hence, fibre thickness is not a parameter in the formulation. Biological tissues, however, exhibit strong variations in fibre thickness defining different fibre hierarchies where the thickness can have a significant influence. This is especially true in inhomogeneous bending and shear-related states of stress.

To overcome this shortcoming, in this work the approach of superimposed continua is extended. While the matrix is still considered as an isotropic continuum, the fibres are modelled as one-dimensional Cosserat continua. Hence, bending and shearing of fibres, in addition to stretching, become meaningful and fibre thickness becomes a material parameter.

For the specific application to myocardial tissue, the muscle fibres are enmeshed in a collagen network. Both, the fibre and the collagen material, are associated each with individual strain energy functions which are combined within a homogenization approach. In this way, a three-dimensional state of stress and strain of the complex myocardial tissue can be addressed.

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