Calculation of Optimal Bounds on the Failure Probability in Overstretched Arteries

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ABSTRACT

Undesired failure of soft biological tissues may e.g. occur in atherosclerotic arteries due to an overexpansion during balloon angioplasty or in aneurysms. This is accompanied by severe risks for the affected patient, since the tissue failure may lead to fatal consequences such as a myocardial infarction, stroke or internal bleeding. A lot of effort is put into predictive finite element analyses of the tissue behavior under the above-mentioned conditions. While a variety of failure criteria has been proposed in the literature, one main challenge is the parametric variability of soft biological tissues with respect to different samples. This leads to an uncertainty of parameters, which enter numerical models and therefore influence the prediction of the failure criterion. In this contribution the authors propose the application of a framework denoted as 'Optimal Uncertainty Quantification' (OUQ) [1], which in principle enables the determination of the sharpest bounds on the probability of failure (PoF) under consideration of statistical information from experiments. Based on a real cyclic experiment of a human carotid artery [2] and the associated response of a constitutive model including damage [2,3] a virtual experimental data set is generated in order to demonstrate the methodology of OUQ. In particular, failure bounds are computed for different levels of statistical information using the *mystic* software framework [4] for two different failure criteria. Then, the relevance of both criteria is investigated for different loading situations in the simulation of a finite element model of a simplified atherosclerotic artery [5]. Moreover, a meta model is derived for the latter finite element calculations, which approximates the maximum volume-averaged damage value per element in dependence on the stiffness of the media. The meta model is used within OUQ to compute bounds on the PoF for different numbers of overstretches of the simplified atherosclerotic artery.

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