6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

A systematic comparison of 3D solid, shell and membrane formulations for the simulation of arterial wall mechanics

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Key Words: *Arterial wall mechanics, membrane, shell, incompressible*

Computational modelling of arterial wall mechanics is now a key component in many areas of vascular disease research. The arterial wall can be modelled, with increasing degree of detail, as a membrane structure, a shell structure or a full three dimensional solid. Depending on the specific application, a choice must be made between these options, reaching a compromise between accuracy and computational cost. When it comes to deciding the optimal option, the decision relies mostly on intuition or previous experience, and is often unclear what the impact on numerical accuracy impact is.

This paper presents a systematic comparison between these three models, using in-house codes previously implemented for different applications. The first model is a nonlinear incompressible membrane model implemented within the software CRIMSON for FSI modelling of the vascular system [1]. The second is a rotationless incompressible shell model, enhanced with extra degrees of freedom (thickness stretch and the hydrostatic pressure), previously used in electromagnetics applications [2]. The third model is a low order three-dimensional model implemented within a Finite Element code for fully incompressible solids, using a new set of conservation laws for solid dynamics [3].

Different idealized geometries and constitutive models are used to compare the accuracy and efficiency of these approaches. Results are also compared to the close form given by an axisymmetric problem, either assuming thin or thick wall assumptions. A general guideline is provided to choose the adequate approach depending on the specific application and geometry.

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