POLITECNICO DI TORINO
Repository ISTITUZIONALE

Refined one-dimensional models applied to biostructures and fluids

Original
Refined one-dimensional models applied to biostructures and fluids / Guarnera, Daniele. - (2019 Mar 08), pp. 1-132. [10.6092/polito/porto/2729363]

Availability:
This version is available at: 11583/2729363 since: 2019-03-26T16:09:45Z

Publisher:
Politecnico di Torino

Published
DOI:10.6092/polito/porto/2729363

Terms of use:
Altro tipo di accesso

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

30 March 2023

Abstract

Fast, reliable and accurate computational methods are highly sought in biomechanics. To reduce the amount of invasive tests and to predict the mechanical response of biological components and anatomic parts, the Finite Element Method is the most popular approach. Despite the accuracy of FEM, the analyses often require prohibitive computational times. This work proposes a novel approach for the analysis of bio-structures and fluids, with low computational cost, based on the use of higher-order 1D models, developed within the Carrera Unified Formulation. Whitin CUF, it is possible to express the unknown field (i.e. velocity, displacements etc.) by using an arbitrary expansion. Refined, hierarchical models can be obtained, where the order of approximation is a free parameter of the analysis. The cross-section is described through the use of the expansion function and the equations are expressed in terms of fundamental nuclei (FN).

A new approach for the computational analysis of anatomic structures based on CUF is presented in this manuscript, called Component-Wise approach (CW). CW allows to model multi-component and multi-material structures through 1D CUF models automatically accounting for the interfaces. First, examples are shown for static and free-vibration analysis of various complex bio-component. Then, extension to nonlinear CUF frameworks is introduced, which is fundamental to model tissues that show high nonlinearities. In this context, the CUF approach provides accurate predictions reducing extremely the analysis time.

Parallel to the structural formulation, 1D CUF models for the Computational Fluid Dynamics (CFD) have been developed. In particular, 1D formulations for incompressible and highly viscous fluids have been derived from Navier-Stokes equations. Similarly to the structural models, Taylor and Lagrange polynomial are used to describe velocity and pressure, even in presence of different boundary conditions. CFD/CUF approach has been extended to *node-dependent* kinematic models (NDK), which is an adavnced modelling method that allows to modify the kinematics of the model node-by-node. This novel techinique allows the enhancement of the approximation only in limited parts of the domain, providing flexibility and reducing furtherly the computational effort.

Validation has been provided for a large number of numerical examples. Typical biomechanics structures, as tendons or arterial tissues, have been analyzed in linear and nonlinear regime. Flows in cylindrical and non-conventional pipes have been investigated, taking into account different velocity profiles. Results show that CUF models, with uniform or variable kinematics, provide accurate and reliable results, in terms of stress/strain fields and flow parameters. The last part of the work has been dedicated to the Fliud-Structure Interaction (FSI), to provide the ground work for a future method for the efficient description of this interaction.

Daniele Guarnera