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[Proceeding] Unified theory of one-dimensional structures and flows with applications to biomedical engineering and coupled problems

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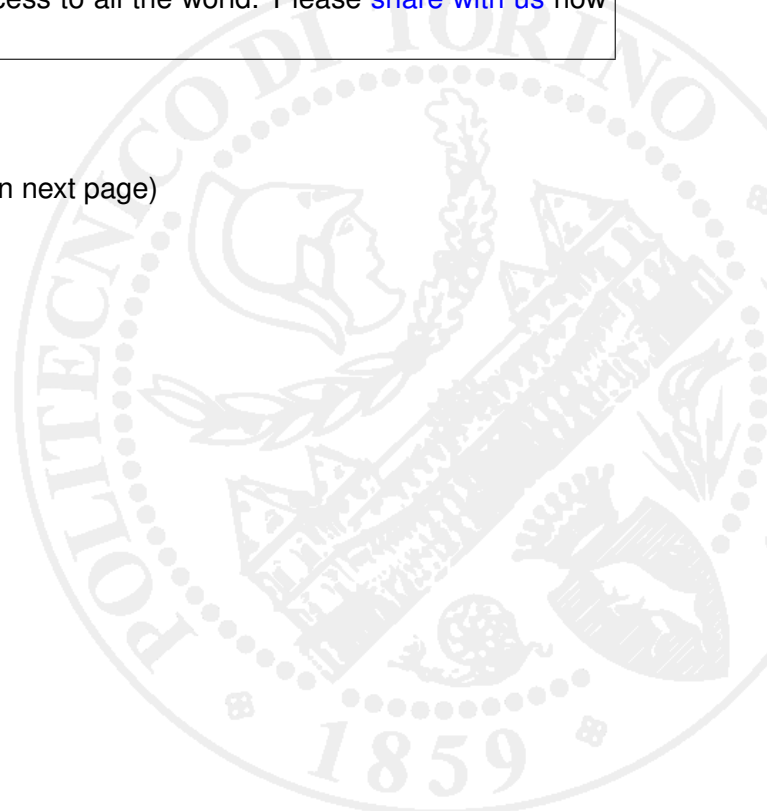
UNIFIED THEORY OF ONE-DIMENSIONAL STRUCTURES AND FLOWS WITH APPLICATIONS TO BIOMEDICAL ENGINEERING AND COUPLED PROBLEMS

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ABSTRACT

Advanced theories for structures and viscous flows are discussed in this work. In the first part, one-dimensional structural beam theories are formulated by employing the Carrera Unified Formulation (CUF). According to CUF [1], the primary mechanical variables are expressed as an arbitrary expansion series of the generalized unknowns. In this manner, by using an index notation, the governing equations are formulated in terms of fundamental nuclei, whose mathematical expressions are formally independent of the theory order. Advanced beam theories with higher-order kinematics can be, therefore, implemented in an automatic and straightforward manner without the need of ad-hoc assumptions. The finite element method is used to obtain numerical solutions, and the enhanced capabilities of the refined CUF-based beam models are widely demonstrated by comparison with literature results and commercial codes. Various problems are considered, and particular emphasis is given to biomedical engineering applications.

Attention is focussed on the extension of CUF to computational fluid-dynamics in the second part of the present work. Similarly as in the structural formulation, CUF is used here to develop, in a unified manner, advanced hierarchical one-dimensional theories for the analysis of Stokes flows with arbitrary accuracy. The accuracy and the numerical efficiency of the present methodology in dealing with laminar, incompressible, viscous, steady flows with arbitrary velocity/pressure fields are established by comparisons with state-of-the-art finite volumes tools and analytical solutions (see Fig. 1).

The 1D CUF fluid-mechanics models are subsequently coupled with 1D CUF structural theories for the fluid-structure analysis of internal flows within deformable structures [2]. The advanced capabilities of the devised tool are widely supported by the results, which provide enough confidence for future research in this direction.
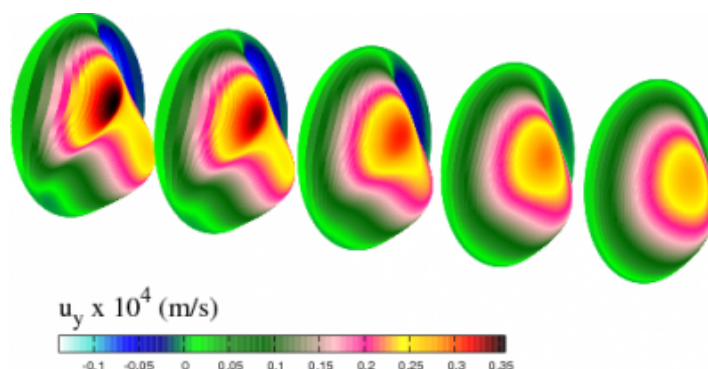
Fig. 1: Axial velocity profiles along the transition zone of a fifth-order inlet velocity flow by 1D CUF model

References

[1] E. Carrera, M. Cinefra, M. Petrolo, E. Zappino, Finite Element Analysis of Structures through Unified Formulation, Wiley & Sons, 2014.

[2] E. Carrera, A. Pagani, A. Varello, Advanced 1D models for fluid-structure interaction of viscous flows in thin-walled cylinders, VI International Conference on Coupled Problems in Science and Engineering, May 18 - 20, 2015, San Servolo Island, Venice, Italy.