Advanced 1D models for fluid-structure interaction of viscous flows in thin-walled cylinders

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ABSTRACT

The Carrera Unified Formulation (CUF) is well established in the literature for over a decade. CUF was originally developed in the framework of solid mechanics for the analysis of plate and shell structures [1] and related multi-field problems [2]. Recently, CUF was successfully extended to the analysis of beams [3,4] and its capability to deal with solid and thin-walled structures as well as with non-homogeneous anisotropic materials has been widely demonstrated.

According to CUF, the problem solution (e.g., the 3D displacement field in the case of displacement-based finite element structural formulations) is expressed as an arbitrary expansion series of the generalized unknowns, which lay either on a curve in the case of 1D theories or on a reference surface in the case of 2D theories. By exploiting a compact notation for the governing equations in terms of fundamental nuclei, advanced theories can be formulated in an automatic manner and without the need for ad-hoc assumptions.

In the present work, CUF is extended to computational fluid-dynamics [5] and used for the formulation of advanced, hierarchical 1D theories for the analysis of Stokes flows. First, the accuracy and the numerical efficiency of the present methodology in dealing with laminar, incompressible, viscous, steady flows with arbitrary velocity/pressure fields is established by comparisons with state-of-the-art finite volumes tools and analytical solutions. The 1D CUF fluid-mechanics models are subsequently coupled with 1D CUF structural theories for Fluid-Structure Interaction (FSI) analysis of flows into thin-walled deformable cylinders.

The enhanced capabilities of the devised CUF/CUF FSI tool are widely supported by the results, which provide good confidence for future research in this direction.

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