Interaction of incompressible flows and thin-walled structures

Abstract:

The coupling of thin, light-weight structures to incompressible flows is a particular challenge within the broad field of computational fluid-structure interaction. The problem is governed by the sensitive and highly non-linear dynamics of slender structures such as shells and membranes in conjunction with the omnipotent incompressibility condition. The contribution presents a partitioned fluid-structure interaction algorithm based on a second order accurate structural solver employing solid shell elements and an Arbitrary Lagrangean Eulerian flow formulation. Stabilized finite elements are used on the fluid domain. Selected aspects of the individual constituents and their interaction are discussed; among them is the problem of conditioning for the shell model, the flow solver satisfying the geometric conservation law and the reliability of the fluid formulation in case of small time steps and distorted mesh. In view of the incompressibility condition the coupling of the two partitions is in particular addressed. It is well-known that sequential coupling approaches, often used for their computational efficiency, may fail in certain situations when the incompressible flow interacts with an extremely
slender low mass structure. It could be shown by a rigorous analysis that this is due to the so-called artificial added mass effect. This is an inherent instability of such schemes that unfortunately cannot be removed by reducing the time steps size. As a remedy a strongly coupled partitioning algorithm is applied iteratively adjusting the interface conditions; here different dynamically adapted relaxation methods can be utilized to accelerate the convergence of the iteration. The use of a fully converged coarse grid solution of the coupled problem as a predictor to the iteration scheme can significantly accelerate its convergence and increase the efficiency of the whole coupling scheme. A selection of two- and three-dimensional numerical examples demonstrates the capabilities of the formulation.

Stichworte: Fluid-structure interaction, finite elements, stabilization methods, geometric conservation law, vectorization

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