Isogeometric Analysis of Fluid–Structure Interaction based on a fully coupled Arbitrary Lagrangian–Eulerian variational formulation

Babak S. Hosseini*[,a], Stefan Turek[a] and Matthias Möller[b]

[a] TU Dortmund University
Institute of Applied Mathematics (LS III)
Vogelpothsweg 87, 44227 Dortmund, Germany
e-mail: {babak.hosseini, stefan.turek}@math.tu-dortmund.de

[b] Delft University of Technology
Delft Institute of Applied Mathematics
Van Mourik Broekmanweg 6, 2628 XE Delft, The Netherlands
email: m.moller@tudelft.nl

ABSTRACT

Current work presents numerical results obtained from the application of a monolithic method for the solution of fluid–structure interaction (FSI) problems, where both the fluid and the solid are allowed to have identical mass densities. In biomechanical contexts such as in the case of blood flow inside an artery, it holds $\rho_f/\rho_s \approx 1$. Partitioned FSI techniques often face instabilities when the solid density ρ_s approaches the fluid density ρ_f (Added mass effect). Besides, for the convergence of a partitioned FSI problem, typically a few rounds of iteration are necessary, where in each round the respective problems are solved one at a time. These deficiencies are avoided by an implicit and monolithic solution approach that takes the full fluid-structure interaction problem as one coupled unity, without partitioning. When modeling the coupled dynamics of FSI, one is confronted with the dilemma that the fluid model is naturally based on an Eulerian perspective while it is very natural to express the solid problem in Lagrangian formulation. The monolithic approach we take, uses a fully coupled Arbitrary Lagrangian–Eulerian (ALE) variational formulation of the FSI problem (cf. [1]) and applies Galerkin-based Isogeometric Analysis for the discretization of the partial differential equations involved. This approach solves the difficulty of a common variational description and facilitates a consistent Galerkin discretization of the FSI problem. For the assessment of the method and validation purposes, we use the 2D FSI benchmarks proposed in [2] and show that our results are in very good consensus with the reference. Besides, the method proved to be very robust for all benchmark test cases. We draw the conclusion that the combination of a fully coupled FSI solution technique with Isogeometric discretizations yields in principle a powerful tool that goes along with the traits high accuracy and robustness. However, the fully coupled approach comes at a cost of high memory requirements and renders the approach not easily applicable to large 3D FSI applications.

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Jordi Girona, 1-3 08034, Barcelona, Spain
Tel. +34 93 405 4697 – Fax +34 93 205 8347
E-mail: iga@cimne.upc.edu

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