Energy stable two-fluid simulation: Div-conforming Isogeometric Analysis meets monolithic time-integration

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ABSTRACT

A monolithic two-fluid formulation is presented that exhibits correct kinetic and potential energy evolution. This results in a guaranteed non-increasing total energy. A correct interface is essential to achieve this. During the interface evolution additional global constraints are enforced using Lagrange multipliers.

The energy proofs require the method to be monolithic, this is made possible by a novel level?set formulation [2]. In this level–set formulation the difficult non-linear Eikonal problem is translated to a simple linear projection problem.

To avoid ambiguities with regard to mass conservation and volume conservationa divergence–conforming NURBS spatial discretization is adopted [3]. The energy properties of the proposed method are verified with the tried and tested dambreak problem. Examining the convergence of the energy evolution demonstrates the potential of the proposed formulation.

The testcase involves low Reynolds–number flow. High Reynolds–number flow would require the use of a stabilized formulation. A stabilized formulation with correct energy behaviour for a single fluid has been developed in parallel [4]. A stabilized formulation for two-fluids is work in progress.

Besides the advantages with respect to stability and improved accuracy the monolithic two-fluid approach also opens the way towards a full newton approach for steady problems. In this case the lengthy time marching towards a quasi-steady solution could potentially be ommitted.

REFERENCES

[1] I. Akkerman, Y. Bazilevs, D.J. Benson, and M.W. Farthing C.E.Kees. Free-Surface flow and fluid object interaction modeling with emphasis on ship hydrodynamics. Journal of Applied Mechanics, 79, 2012.

[2] I. Akkerman. Monotone level-sets on arbitrary meshes without redistancing. Computers & Fluids, 146:74 – 85, 2017.

[3] J.A. Evans and T.J.R. Hughes. Isogeometric divergence-conforming B-splines for the unsteady Navier–Stokes equations. Journal of Computational Physics, 241:141–167, 2013.

[4] M.F.P. ten Eikelder and I. Akkerman. Correct energy evolution of stabilized formulations: The relation between the variational multiscale approach and the Galerkin/least-squares method via dynamic orthogonal small-scales and isogeometric analysis. II: The incompressible Navier–Stokes equations Computer Methods in Applied Mechanics and Engineering, 340:1135–1154, 2018.