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A unified approach for flow simulation of compressible and incompressible fluids LARS PESCH, MONIKA POLNER, JAAP VAN DER VEGT, University of Twente — In many fluid dynamics problems one has to deal with flows which exhibit in some regions conditions under which the fluid is compressible, while in other regions it behaves essentially incompressible. To simulate such flows is a problem for many mathematical methods that are either tailored towards compressible or incompressible fluids. Also the inclusion of complicated equations of state, necessary to describe the physics of complex fluids, raises difficulties. A mathematical framework that can overcome these difficulties is provided by the use of the symmetrized compressible Navier-Stokes equations using entropy variables. In the presented method, these equations are solved with a Galerkin least-squares finite element method which provides the necessary flexibility to deal with a wide range of flow problems. A critical component in the algorithm is the use of a stabilization operator. Using dimensional analysis we have derived and analyzed a class of stabilization operators which is suitable for both compressible and incompressible flows, resulting in a unified mathematical framework. A key feature of the algorithm is its close relation to the underlying thermodynamics, which is incorporated by expressing the equations of state in terms of two material coefficients, volume expansivity and isothermal compressibility, which are available in analytical or tabulated form for relevant substances. The algorithm will be demonstrated with test cases for both fully incompressible as well as compressible fluids to underline the feasibility of the approach.

Lars Pesch
University of Twente

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