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Stabilized Isogeometric Discretization of the Navier-Stokes-Korteweg Equations: Toward Predictive Cavitation Simulations

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Abstract

Cavitating flows are ubiquitous in engineering and science applications. Despite their significance, a number of fundamental problems remain open; and our ability to make quantitative predictions is very limited. The Navier-Stokes-Korteweg equations constitute a fundamental model of cavitation [1], which has potential for predictive computations of liquid-vapor flows, including cavitation inception —one of the most elusive aspects of cavitation. However, numerical simulation of the Navier-Stokes-Korteweg equations is very challenging, and state of the art simulations are limited to very small Reynolds numbers, open flows (no walls), and in most cases, micrometer length scales [2-3]. The computational challenges emerge from, at least, (a) the presence of third-order derivatives in the governing equations, (b) a complicated eigenstructure of the spatial partial-differential operators in the governing equations, which prevents the use of standard finite volume techniques, and (c) the need to resolve the liquid-vapor interface, which without special treatment, has a thickness in the order of nanometers. Here, we present a stabilized isogeometric discretization scheme that permits, for the first time as far as we are aware, large-scale simulations of wall-bounded flows with large Reynolds numbers. The proposed stabilization scheme is a residual-based approach that emanates from the eigenstructure of the equations and vastly outperforms standard stabilization schemes for advection-dominated problems. We feel that this work opens possibilities for predictive simulations of cavitation.