A THREE-SCALE VARIATIONAL MULTISCALE METHOD FOR INCOMPRESSIBLE TURBULENT FLOWS IN DOMAINS WITH MOVING BOUNDARIES

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We present a residual-based turbulence model for the incompressible Navier-Stokes equations for moving domain problems. The method is derived employing the Variational Multiscale (VMS) framework and it is cast in an Arbitrary Lagrangian Eulerian framework to accommodate the moving boundaries. The underlying idea of the VMS framework is a multiscale decomposition of the continuous solution fields. In the present work, this decomposition leads to three coupled nonlinear problems that are termed as the coarse-scale, the fine-scale level-I and fine-scale level-II problems. The coarse-scale problem governs the resolved scales, while the two fine-scale problems govern the scales that have wavelength shorter than the characteristic size of the mesh. The solution of the fine-scale level-II problem is variationally projected on to the fine-scales level-I problem to stabilize it. Then, the solution of the fine-scales level-I problem is injected in the coarse-scale problem with the dual goal of serving as a turbulence model as well as providing stability to the coarse-scale problem. The two fine-scale problems are modeled using bubble functions that allow deriving the turbulence models without any embedded tunable parameter. Another significant feature of the method is that the two fine-scale components are driven by the residual of the coarse-scale fields, and therefore the method is consistent with respect to the governing equations. The present approach yields turbulence models that are highly accurate even for unstructured low-order tetrahedral meshes.
Numerical accuracy of the proposed method is shown on a turbulent channel flow at Re= 395 with oscillating walls. To show the applicability and accuracy of the method on industrial strength problems, we also study a plunging SD7003 airfoil at Re= 40,000 and Re= 60,000. All the numerical tests are performed using low order hexahedral and tetrahedral meshes.