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THE METHOD OF SUBGRID VORTICES: AN ISOGEOMETRIC STRUCTURE-PRESERVING APPROACH TO VARIATIONAL MULTISCALE MODELING OF TURBULENCE

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In this talk, we present a novel approach to variational multiscale modeling of turbulence which combines the best features of multiscale, isogeometric, and structure-preserving methods in computational fluid dynamics. Our objective is an intuitive and effective subgrid-scale model for isogeometric divergence-conforming discretizations of the incompressible Navier-Stokes equations [1] that preserves the geometric balance law structure of incompressible fluid flow. The basis of our approach is simple - locally enrich the solution space with divergence-free subscale functions whose supports are confined to single elements, allow the subscales to "slip" along element boundaries, and weakly enforce no-slip boundary conditions element-wise on the subscale solution. By allowing the subscales to "slip" along element boundaries, the method is able to account for shear layers in subscale quantities without directly resolving them. If desired, subgrid viscosity may also be included to introduce an additional dissipation mechanism that does not act on large flow structures. Mathematically speaking, we approximate residual-free bubbles using tangentially discontinuous enrichment functions, and hence the method may be interpreted as a residual-driven variational multiscale method. Physically speaking, we introduce a computable set of subgrid-scales, the subgrid vortices, and model the effect of unresolved flow features on coarse resolved scales directly by coupling the coarse-scales with the "fine" subgrid vortices. As the coarse resolved scales and subgrid vortices are both divergence-free, the resulting methodology conserves mass point-wise and admits discrete balance laws for momentum, energy, enstrophy, and helicity. We will discuss various mathematical properties of the proposed approach, present relevant numerical computations in the context of turbulence modeling for incompressible flows, and discuss extension of our approach to complex flows such as those governed by the equations of incompressible magnetohydrodynamics.

REFERENCES

[1] Evans JA, Hughes TJR (2013) Isogeometric divergence-conforming B-splines for the unsteady Navier-Stokes equations. *J. Comp Phys* **241**:141-167.