ISOGEOMETRIC AND VARIATIONAL MULTISCALE METHODS IN COMPUTATIONAL FLUID DYNAMICS*

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ABSTRACT

I will begin with a brief description of NURBS-based Isogeometric Analysis, and I will illustrate that this technology is capable of high-fidelity geometric modeling and exhibits superior approximation and robustness properties compared with traditional finite element methods in Computational Fluid Dynamics. Applications include advection-diffusion processes, phase-field modeling, fluid-structure interaction, and flows with rotating components. I will then proceed to a description of the Variational Multiscale (VMS) Method and its application to turbulent incompressible flows. I will focus on a residual-driven version of the method that may be viewed as a VMS analog of Large Eddy Simulation. I will then show that quadratic and higher-order NURBS are capable of very accurate solutions of turbulent flow problems, and argue that this is due to their accurate representation of higher-wave-number components of the flow. I will then compare weakly enforced wall boundary conditions, based on stabilized Discontinuous Galerkin and law-of-the-wall concepts, with strongly enforced wall boundary conditions. The superiority of the weakly enforced version will be apparent and I will argue that it provides an efficient and practical approach to complex turbulent flow problems somewhat analogous to the Detached Eddy Simulation philosophy. (Some of the work presented in the talk is described in recent publications [1-6].)

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REFERENCES

[1] Y. Bazilevs, V.M. Calo, J.A. Cottrell, T.J.R. Hughes, A. Reali, and G. Scovazzi, Variational multiscale residual-based turbulence modeling for large eddy simulation of incompressible flows, *Computer Methods in Applied Mechanics and Engineering,* Vol. 197, 173-201, 2007.

[2] H. Gomez, V.M. Calo, Y. Bazilevs, and T.J.R. Hughes, Isogeometric Analysis of the Cahn-Hilliard phase-field model, *Computer Methods in Applied Mechanics and Engineering,* Vol. 197, 4333-4352, 2008.

[3] I. Akkerman, Y. Bazilevs, V.M. Calo, T.J.R. Hughes, and S. Hulshoff, The role of continuity in residual-based variational multiscale modeling of turbulence, *Computational Mechanics,* Vol. 41, 371-378, 2008.

[4] Y. Bazilevs, V.M. Calo, T.J.R. Hughes, and Y. Zhang, Isogeometric fluid-structure interaction: Theory, algorithms and computations, *Computational Mechanics,*

Vol. 43, 3-37, 2008.

[5] Y. Bazilevs and T.J.R. Hughes, NURBS-based Isogeometric Analysis for the Computation of Flows about Rotating Components, *Computational Mechanics*, Vol. 43, 143-150, 2008.

[6] H. Gomez, T.J.R. Hughes, X. Nogueira, and V. Calo, Isogeometric analysis of the isothermal Navier-Stokes-Korteweg equations, *Computer Methods in Applied Mechanics and Engineering,* to appear, 2010.