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Advancing Reynolds Stress Modeling for Non-equilibrium Turbulence with DNS and Data-driven Approaches

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ABSTRACT:

Despite their inherent potential advantages, Full Reynolds Stress Models (RSMs) remain less widely used in engineering than eddy-viscosity models (EVMs) due to challenges in computational cost, numerical robustness, and inconsistent accuracy. Both EVMs and RSMs struggle to predict strongly non-equilibrium and separated flows, despite the inclusion of exact terms in the RSM equations intended to capture these effects. Recent advancements, leveraging a concert of Direct Numerical Simulation (DNS) and data-driven methods, have enabled significant progress in turbulence modeling. This presentation highlights our work to improve RSM predictive capability for stratified wake flows and boundary layers under adverse pressure gradients. By refining models for dissipation anisotropy and pressure diffusion and using DNS ensembles to recalibrate pressure redistribution sub-models, we have enhanced RSM performance for wake decay dynamics and incipiently separated flows. These advances not only improve accuracy but also provide deeper insights into the limitations of traditional models and guide the development of next-generation turbulence models for complex aerodynamic and hydrodynamic applications

BIOGRAPHY:

Dr. Robert Kunz is a Professor of Mechanical Engineering at Penn State University. His research interests include Computational Fluid Dynamics (CFD), Multiphase Flows, Turbomachinery, Nuclear Reactor Thermal Hydraulics, Naval Hydrodynamics and Turbulence. Dr. Kunz joined the MNE department in 2017 after working as an engineer and researcher at Pratt and Whitney, General Motors, Knolls Atomic Power Laboratory, and, from 1997-2016, at Penn State's Applied Research Laboratory. He has taught classes at PSU in Compressible Flow, CFD, Aero-propulsion, Turbomachinery, Engineering Mathematics, and Multiphase Flow Modeling in CFD. Dr. Kunz has advised numerous PhD and MS theses at Penn State, is a Fellow of ASME, and currently serves as the Associate Department Head for Graduate Programs in Mechanical Engineering.