MAE *Seminar* SERIES

A Kinetic Description of Morphing Continuum and Its Applications in Fluid Mechanics

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ABSTRACT

The coupling between the intrinsic angular momentum and the linear momentum has been known to be prominent in fluid flows involving physics across multiple length and time scales, e.g. turbulence, nonequilibrium flows and flows at micro-/nano-scale. Since the classical Navier-Stokes equations and Boltzmann's kinetic theory are derived on the basis of monatomic gases or volumeless points, efforts to derive constitutive equations involving intrinsic rotation for fluids of polyatomic molecules have been found since the 1960s. One of the proposed continuum theories for polyatomic molecules was Morphing Continuum Theory (MCT). The theory was originally formulated under the framework of rational continuum mechanics and thermodynamic irreversible processes. The mathematically rigorous continuum mechanics presents a complete and closed set of governing equations, but leaves the physical meanings unexplained. Similar to the correlation between Boltzmann's kinetic theory and the classical continuum mechanics, an advanced kinetic theory involving the Boltzmann-Curtiss (B-C) distribution function and the B-C equation will be introduced for a morphing continuum. The method of the most probable distribution method is used to derive the Boltzmann-Curtiss distribution. It will be demonstrated that the corresponding Boltzmann-Curtiss equations are the MCT governing equations without any dissipation terms when the system (flows with inner structures) is in equilibrium and at the Boltzmann-Curtiss distribution. A first-order approximation to the B-C distribution will be used to further derive the B-C transport equations. The corresponding governing equations will then be compared with the MCT equations. Preliminary results for using MCT in multiple aerospace related applications, i.e. turbulence, and high speed gaseous flows will be showcased and discussed.

BIO SKETCH

Dr. James M. Chen is an Assistant Professor and the Steve Hsu Keystone Research Faculty Scholar at Kansas State University. He earned his B.S. at National Chung-Hsing University (2000), M.S. at National Taiwan University (2005) and Ph.D. at The George Washington University (2011). He joined Kansas State University as an Assistant Professor in 2015. Prior to joining K-State, he was a faculty of engineering in the Penn State University system (2012-2015). He has published more than 30 peer-reviewed journal articles in multiscale computational mechanics, fracture mechanics, theoretical & computational fluid dynamics and atomistic simulation for thermo-electro-mechanical coupling at nanoscale. He received the Young Investigator Award from Air Force Office of Scientific Research in 2017. His research at MCPL has been supported by AFOSR, NSF and NASA. His current interests are on the kinetic description of Morphing Continuum, compressible turbulence, supersonic/hypersonic flows, atomistic electrodynamics, triboelectricity and high-level programming.