Department of Mechanical Engineering

The Pratt & Whitney
Distinguished Lecture

A Multi-Fidelity Design Strategy for Combustion Dynamics in Propulsion Engines

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(Refreshments will be served before the lecture)

This lecture will address a multi-fidelity modeling strategy to facilitate data-enabled design of combustion devices for propulsion engines. As a specific example, the issue of combustion instability (i.e., unsteady flow motions in combustion chambers) will be discussed. An interdisciplinary research will be presented for the development of an efficient and robust capability to understand, analyze, and predict combustion dynamics in contemporary and future propulsion systems. The effort requires extensive knowledge in supercritical combustion, combustion instabilities, reduced-basis modeling (emulation), statistics, uncertainty quantification, and machine learning. Recent breakthroughs in modeling and data analytics techniques are utilized to substantially improve the modeling capabilities at all levels. New techniques will be discussed to address issues specific for physics extraction and design evaluation of a complex system such as rocket and gas turbine engines. The effect of all known parameters (e.g., design attributes and operating conditions) on the system stability behavior will be surveyed effectively and efficiently, with practical turn-around times.

The integrated approach starts with LES-based high fidelity modeling and simulations of combustion dynamics in engines. Reduced-basis models and emulation then leverages the database established by LES for a physics-based data assimilation. Stochastic-based extraction of physics from complex flowfields provides faithful and interpretable representations of underlying mechanisms. Feature extraction techniques are incorporated into a spatio-temporal surrogate model built upon machine-learning techniques such as Gaussian process (GP) regression. Combined with statistical methodologies and control theories, these techniques allow for an efficient survey of flow evolution and combustion dynamics, with special attention focused on the identification of combustion response and gas dynamic driving mechanisms. Data-driven quantification of the transfer function between the identified mechanisms will be achieved. Finally, a system-level model will be developed for effective and efficient assessment of the combustion stability behaviors of a practical system with complex geometry over a broad range of operating conditions.

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Prof. Vigor Yang is the William R. T. Oakes Professor and Chair of the School of Aerospace Engineering at the Georgia Institute of Technology. He has published 10 comprehensive volumes and numerous technical papers on combustion, propulsion and energetics. He was the recipient of the Air-Breathing Propulsion Award (2005), the Pendray Aerospace Literature Award (2008), the Propellants and Combustion Award (2009), and the von Karman Lectureship in Astronautics Award (2016) from the American Institute of Aeronautics and Astronautics (AIAA); the Worcester Reed Warner Medal (2014) from the American Society of Mechanical Engineers (ASME); and the Lifetime Achievement Award (2014) from the Joint Army, Navy, NASA, and Air Force (JANNAF) Interagency Propulsion Committee. Dr. Yang was the editor-in-chief of the AIAA *Journal of Propulsion and Power* (2001-2009) and the JANNAF *Journal of Propulsion and Energetics* (2009-2012). He is currently a co-editor of the Aerospace Book Series of the Cambridge University Press (2010-). A member of the U.S. National Academy of Engineering and an Academician of Academia Sinica, Dr. Yang is a fellow of the AIAA, ASME, and Royal Aeronautics Society (RAeS).