Mechanical & Aerospace Engineering

seminar

Thermal Nonequilibrium in Scramjet Combustion

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abstract

Scramjet engines provide a robust approach for achieving supersonic flight. Here, the intake air is compressed using a system of shocks before entering the combustion chamber. Since the fluid velocity is very high, fuel-air mixing and ignition in the combustor have to proceed very fast in order to sustain propulsive thrust. Moreover, the efficiency of the shock-based compression relies on the system maintaining sufficiently high velocities. Due to this intricate coupling, the effect of shock-based compression on the subsequent combustion processes is of immediate interest. In this work, we look closely at the impact of shocks on the molecular motion of post-compression air. It is well known that compression shocks introduce internal nonequilibrium, whereby the energy distribution amongst the different internal energy modes are altered. Since chemical reactions can be highly sensitive to such variations, this effect could adversely impact combustion stability.

This talk describes the computational modeling effort for understanding such shock-combustion interactions. Specially, a first-principles based quasi-classical trajectory approach is used to determine the modified reaction rates in the presence of shocks. Using these rates in direct numerical simulations of model scramjet engines, the effect on mixing and ignition is studied.

abstract cont'd Contrary to theoretical expectations, it is shown that shocks actually enhance ignition by accelerating certain key chemical reactions in hydrogen-air combustion. These studies point to novel design options for enhancing combustor stability.

biosketch

Dr. Venkat Raman is currently an Associate Professor at UM Ann Arbor. Prior to this, he was first an Assistant (2005-2011) and then Associate Professor (2011-2014) at The University of Texas at Austin, where he has also held the Eli H. and Ramona Thornton Centennial Fellowship in Engineering. He received his PhD from Iowa State University in Chemical Engineering (2003) and was a postdoctoral fellow at the Center for Turbulence Research at Stanford University (2003-2005). His research focuses on high-fidelity modeling of turbulent combustion for propulsion and power generation, focusing on turbulence-chemistry interaction, uncertainty quantification, numerical error analysis and first-principles chemistry modeling. He is a recipient of the NSF CAREER Award (2008), and recently became an Associate Fellow of AIAA (2016).