ESSCI Spring 2018 Technical Meeting

Hypersonic Propulsion: Challenges in Thermal Management and Flame Stabilization over a Range of Flow Conditions

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Over the last six decades, research on hypersonic propulsion has seen several cycles of resurgent interest, typically at fifteen to twenty year intervals. We are currently in the midst of another peak cycle with worldwide interest in hypersonic propulsion. The fundamental challenges remain nearly the same, i.e. inlet design and mass capture, shockwave-boundary layer interactions, flow distortion and fuel-air mixing, flame holding over recirculation regions, turbulence-chemistry interactions, thermal management with endothermic fuels, etc. Advances in synthesis of high-temperature materials and metal additive printing capabilities are expected to rapidly accelerate the process of finding engineering solutions to several of the above challenges.

In this presentation, recent work at the University of Virginia on the endothermic-fuel cooling concepts with and without catalysts will be discussed. The attempts to control or mitigate the fuel coking phenomena using fixed-bed and wall-coated flow reactor investigations will be presented. Specifically, recent results from fuel-catalyst pairing investigations, including extension to 3D printed cooling channels with super alloy Inconel 718, will be discussed.

Investigations on flame stabilization under dual-mode combustion conditions, corresponding to a flight Mach number of about five, are also being pursued at the University of Virginia. A host of advanced diagnostic methods (PIV, OH and CH2O PLIF, CARS) and computational methods is used to better understand the fundamental flame holding mechanism. In particular, the effects of fuel-air premixing, scaling of the cavity recirculation region, and turbulent mixing will be presented for a range of high-speed flow conditions.