DIRECT NUMERICAL SIMULATIONS OF LOX/H_2 TEMPORAL MIXING LAYERS UNDER SUPERCRITICAL CONDITIONS[#]

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Direct Numerical Simulations (DNS) of a supercritical LOX/H_2 temporal three-dimensional mixing layer are conducted for the purpose of exploring the features of high pressure mixing behavior. The conservation equations are formulated according to fluctuation-dissipation (FD) theory which is not only totally consistent with non-equilibrium thermodynamics, but also relates fluxes and forces from first principles. According to FD theory, complementing the low-pressure typical transport properties (viscosity, diffusivity and thermal conductivity), the thermal diffusion factor is an additional transport property which may play an increasingly important role with increasing pressure. The Peng-Robinson equation of state with a correction for obtaining accurate molar volumes, in conjunction with appropriate mixing rules, is coupled to the dynamic conservation equations to obtain a closed system. The boundary conditions are periodic in the streamwise and spanwise directions, and of non-reflecting outflow type in the cross-stream direction. Following the DNS protocol, the studied temperature/pressure regime is one where both Kolmogorov and Batchelor scales can be resolved for pseudo-species (i.e. species with transport properties modified to allow the attainment of large enough Reynolds numbers). Correlations for the Schmidt and Prandtl numbers as functions of the thermodynamic variables, based on exact fluid properties, are used to ensure that correct relative transport processes are employed. Due to the strong density stratification, the layer is considerably more difficult to entrain than equivalent Reynolds number gaseous, droplet-laden or supercritical heptane/nitrogen layers.

A preliminary simulation conducted with an initial Reynolds number of 600, an initial convective Mach number of 0.4 and temperatures of 400 K in the lower LOX stream and 600 K in the upper H_2 stream eventually exhibits distorted regions of high density gradient magnitude similar to the experimentally observed 'wisps' of fluid at the boundary of supercritical jets. The temperature stratification was chosen to yield the maximum density stratification for which the computation can be spatially resolved at this Reynolds number due to memory constraints. In this preliminary simulation, the layer does not exhibit transition to turbulence because the small scales formed as a result of pairing and entertainment are damped by the regions of high density gradient which act similar to material interfaces. The characteristics of this layer, as well as those of others, with larger initial Reynolds numbers and in different temperature regimes, are discussed and interpreted in the context of turbulence transition and LOX disintegration.

[#]Sponsored by the National Aeronautics and Space Administration, Marshall Space Flight Center, under the direction of Dr. John Hutt. The computational resources were provided by the JPL Supercomputing Center.