Large Eddy Simulations of Temporal Mixing Layers Under Supercritical Conditions

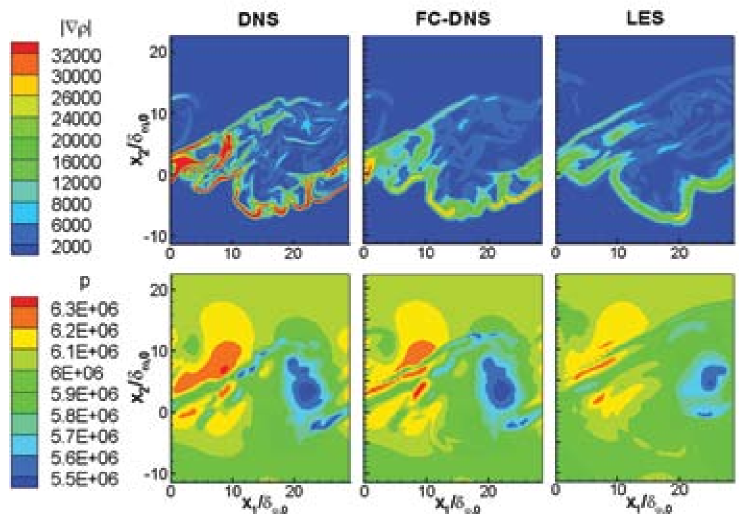
The operating pressures of advanced propulsion devices, such as gas turbines, diesel engines, and liquid rockets, exceed the thermodynamic critical pressure of the fuel or oxidizer during many instances of their wide range of operating conditions. When the critical pressure of the fluid is exceeded, the fluid disintegration and mixing processes exhibit distinctive features not present under atmospheric conditions.

To investigate fluid behavior under high-pressure conditions, a Large Eddy Simulation (LES) study was conducted for three-dimensional, supercritical temporal mixing layers undergoing transition to turbulence. This study will allow NASA missions to achieve more efficient engine designs for both aircraft and spacecraft by providing insight into the physics of supercritical mixing.

In LES, only the large scales of fluid motion are resolved while the small scales are modeled. The main objective of this study is to analyze and develop models for LES using previously produced direct numerical simulation (DNS) data where all scales of flow motion are resolved.

Two binary-species mixtures have been simulated at high pressures: oxygen/hydrogen (10MPa) and heptane/nitrogen (6MPa), described by equations suitable for real-gas non-ideal mixtures.

The simulations used a 6th-order compact finite-difference scheme (with a parallel tri-diagonal solver) and 4th-order Runge-Kutta time integration. This model is implemented in a parallel solver using Message Passing Interface (MPI) and the domain decomposition methodology. The code is written in FORTRAN 90 and run on Jet Propulsion Lab's shared-memory multiprocessor SGI Altix 3700 systems.



Shown are the density gradient magnitude (kg/m4) and non-dimensional pressure solutions obtained from DNS, an ideal Large Eddy Simulation (LES) template (FC-DNS), and our LES results. Results have a grid reduced number of nodes by a factor of 64 with respect to the grid on which the DNS was computed.

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