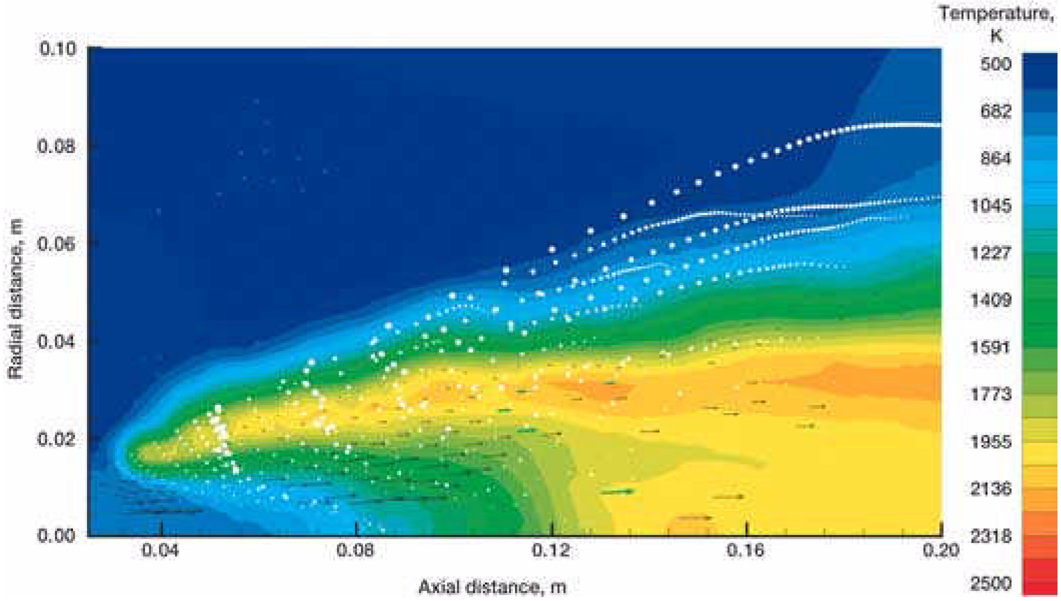
Spray and High-Pressure Flow Computations in the National Combustion Code (NCC) Improved



Global features of a spray flame showing temperature distribution, velocity vector plot, and droplet locations.

Sprays occur in a wide variety of industrial and power applications and in materials processing. A liquid spray is a two-phase flow with a gas as the continuous phase and a liquid as the dispersed phase in the form of droplets or ligaments. The interactions between the two phases--which are coupled through exchanges of mass, momentum, and energy--can occur in different ways at disparate time and length scales involving various thermal, mass, and fluid dynamic factors. An understanding of the flow, combustion, and thermal properties of a rapidly vaporizing spray requires careful modeling of the rate-controlling processes associated with turbulent transport, mixing, chemical kinetics, evaporation, and spreading rates of the spray, among many other factors.

With the aim of developing an efficient solution procedure for use in multidimensional combustor modeling, researchers at the NASA Glenn Research Center have advanced the state-of-the-art in spray computations in several important ways:

1. With the development of LSPRAY (ref. 1) and EUPDF (ref. 2), we were able to extend and demonstrate the use of the joint scalar Monte Carlo Probability Density Function (PDF) approach to the modeling of spray flames for the first time. In this approach, the mean gas-phase velocity and turbulence fields are determined with a conventional computational fluid dynamics method, the scalar fields ofspecies and enthalpy from a modeled PDF transport equation using a Monte Carlo method,

and the liquid-phase representation from a Lagrangian-based dilute spray model. The application of this method clearly demonstrated the importance of chemistry-turbulence interactions in the modelingof reacting sprays (refs. 3 and 4).

2. To facilitate large-scale combustor applications, we extended the spray and Monte Carlo PDF computations to parallel comput-ing and unstructured grids. The unstructured three-dimensional solver, which is designed to be massively parallel, accommodates the use of an unstructured mesh with mixed elements composed of triangular, quadrilateral, and/or tetrahedral elements. The ability to perform the computations on unstructured meshes enables researchers to represent complex geometries with relative ease (ref. 5).

3. To account for nonideal gas behavior under critical and supercritical conditions, we integrated a high-pressure equation of state into the gas-phase flow solver and added the effect of high pressure on transport properties in the gas phase.

The modeling approach used in LSPRAY and EUPDF provided favorable results when applied to several different spray flames representative of those encountered in both gas-turbine combustors and stratified-charge rotary combustion (Wankel) engines (refs. 3 to 5). The source code of LSPRAY and EUPDF will be available with the National Combustion Code (NCC) as a complete package. The models will be validated further at realistic temperatures and pressures.

References

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