Combustion

While during the 2000 CTR summer program the combustion group had strong participation from industry, assessing the merits of large-eddy simulation (LES) of combustion problems, both the feasibility and the benefits of combustion LES now seem to be well-established facts. The combustion and sprays group of the 2002 CTR Summer Program was largely dominated by projects addressing theoretical and modeling questions with relevance to applications in complex systems. This section includes reports on six projects, four related to combustion modeling and two on multiphase flows.

Selle *et al.* report on the LES of an industrial power-generation gas-turbine combustor using the so-called Thickened Flame combustion model. Since CO is a major concern in gas-turbine combustion, this model, which was based on one-step global chemistry, has been extended to account for a two-step chemical scheme including carbon monoxide and validated with flame/vortex interaction DNS data. Simulations are performed for the non-reactive and reactive cases and results are compared with velocity and temperature measurements.

Also related to combustion of stationary gas turbines is the project of Polifke and Wall. An efficient alternative to performing CFD for an entire engine in studying combustion instabilities, is the use of acoustic multi-port or network representations of the thermo-acoustic system. For this approach, the thermo-acoustic transfer matrices of individual components of the network have to be known. Here it is suggested that these matrices could be determined from LES of generic components, and simulations are performed for a simple geometry without heat release. It is shown that the formulation of inflow and outflow boundary conditions is a critical aspect of this work and a new formulation is proposed.

The physics of large-scale fires are dominated by the strong coupling of fluid dynamics, soot formation, and radiation. In numerical simulations these complex interactions are usually not adequately accounted for. As a first step towards fully-coupled simulations Rawat *et al.* performed an LES of a pool fire of one meter diameter, employing an unsteady flamelet model including a kinetically-based soot model and a simplified description of radiative transport. The effect of using a simplified model for radiation is assessed by post-processing the LES results with a detailed radiation model.

Models for scalar mixing are formulated and evaluated with DNS data in the project of Fox *et al.*. The Lagrangian Spectral Relaxation model to describe scalar dissipation rates, and the Lagrangian Fokker-Planck (LFP) model, describing the scalar mixing process of two scalars given the dissipation rates, have been developed by Fox in recent years. Here, the LFP model is extended to account for multi-scalar mixing and chemical reactions. The model is validated with DNS data for three-component mixing and for reactive scalars.

In practical combustion devices, fuel is often supplied as liquid spray or as solid particles. In numerical simulations it is usual to apply Lagrangian particle methods describe the evolution of droplets and particles. In both the projects of Kaufmann *et al.* and of Réveillon *et al.*, Eulerian formulations for a dispersed phase are developed. Kaufmann *et al.* develop a formulation for mono-disperse particles, containing a newly-appearing sub-grid stress term, which is demonstrated to be of importance. The formulation with the modeled stress term is applied in a DNS of particle dispersion in isotropic turbulence. Results are compared with a DNS using a Lagrangian formulation.

The main difference in the formulation of Réveillon *et al.* is that it is for polydisperse evaporating sprays. A multi-fluid method is developed, in which equations for number density, droplet momentum, and droplet kinetic energy are solved for each individual size class. Two-dimensional DNS for two-phase flows with evaporation are performed using a Lagrangian and the multi-fluid method. In a comparison with the DNS results, the model is shown to perform well in predicting spray dynamics and evaporation.

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