Boulder Fluid Dynamics Seminar Series

Tuesday, February 18, 2014
3:30pm-4:30pm (refreshments at 3:15pm)
Bechtel Collaboratory in the Discovery Learning Center (DLC)
University of Colorado at Boulder

The Challenges of Wind Plant Aerodynamics Simulation

Matthew Churchfield, *National Renewable Energy Laboratory*

Within a wind plant exists a complex aerodynamic situation in which we find shear and buoyancy-driven turbulence of the atmospheric boundary layer, wind turbine wakes, and terrain induced flow structures. All of these components interact with one another, affect wind plant performance, and impose mechanical loads on the individual turbines. Because of the large scale and unsteady nature of wind plant aerodynamics, it is difficult to gain understanding through comprehensive field measurements, so simulation is playing an increasingly important role. This talk will give background on the wide range of wind-plant-aerodynamics simulation strategies, and then focus on the large-eddy simulation/actuator line approach being used at the National Renewable Energy Laboratory.

Revisiting the Zeldovich spontaneous reaction wave propagation concept

David R. Kassoy, *University of Colorado, Boulder*

A quantitative, mathematical model for one-dimensional planar spontaneous wave propagation, conceptualized by Zeldovich (Comb. Flame, 39, 211-214, 1980), is developed using systematic, rational asymptotic methods. Zeldovich's intuitive, qualitative description presupposes a continuous sequence of constant volume thermal explosions propagating down an initially imposed negative temperature gradient in the absence of interaction between neighboring fluid particles. This restriction means that the gas remains motionless as the localized, transient thermal power addition occurs. The present analysis describes the complete thermomechanical response of a reactive gas to localized chemical heat release from a one-step Arrhenius reaction during the induction phase of a propagating thermal explosion. The induction time is assumed small compared to the local acoustic time. The derived reduced internal energy equation describes the temperature variation due to constant volume heat addition from a chemical source. However, the asymptotic analysis of the mass and momentum conservation equations, along with the perfect gas equation of state, shows that the process is only nearly constant volume, with the basic pressure rising with temperature in the context of asymptotically small changes in density. A pressure gradient compatible with the spatial temperature distribution is the source of a low Mach number gas expansion no matter how fast the energy deposition occurs. In other words, the asymptotic analysis is used to couple the gas motion to the constant volume heating. Analytical solutions are given for the transient, spatially distributed temperature field, the related pressure field and the velocity field induced by the pressure gradient. Each solution contains a thermal explosion singularity, related directly to the spatial distribution of the initial imposed temperature gradient. The analytical results demonstrate that the thermal explosion propagates down the negative temperature gradient at a supersonic speed. These results demonstrate that the Zeldovich concept of constant volume thermal explosions propagating down an existing temperature gradient must be modified to include thermally induced gas motion. In addition, the expanding hot spot is identified as a source of gasdynamic disturbances (acoustic and/or shock waves) that can propagate into gas beyond the initial temperature inhomogeneity as described by Kassoy (J. Eng. Math, 68, 249-262, 2010) in a study of the thermomechanical response of an inert gas to external thermal energy addition. The present quantitative generalization of the Zeldovich concept has significant consequences for understanding detonation initiation, engine knock and mechanical disturbances observed in unstable liquid rocket engines.