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Numerical Prediction of Vaporizing Spray by using Large Eddy Simulation in Swirling Flows

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Abstract

Large Eddy Simulation(LES) of turbulent spray combustion flow was conducted. An experimental database for the laboratory spray combustor is chosen to validate the present numerical simulation. The governing equations for the gas phases are discretized in three-dimensional curvilinear boundary-fitted coordinate system, and the fuel droplet motion equations are described in Lagrangian representation.

The numerical results are compared with the experiment for the gas-phase mean velocities and its fluctuation in cold flow condition. Three dimensional vortical structures are well visualized and droplet motion is well predicted.

Keywords: *LES, spray, vaporization*

1 Introduction

Numerical simulations of spray combustion phenomena are currently carried out using steady state approach such as Reynolds-averaged Navier Stokes approaches (RANS). However, these models have limitation to predict unsteady features of combustion flows. Large Eddy Simulation (LES) is one of the alternative approach to resolve such problems. LES achieved good prediction such as unsteady flow field, particle laden flows[2], and turbulent gas combustion flows[3]. In the present study, these models are extended and applying to the spray combustion. A laboratory model combustor is subjected as the preliminary stage of this computation.

2 Numerical Approaches

Governing equations for flow field(gaseous phases) are mass, momentum, and mixture fraction conservation equation. Spray droplets is described using Lagrangian representation. Properties of the droplets estimated by solving a system of three equations, for its position, its diameter, and its velocity respectively. Mass vaporization and drag force are also considered in these equations.

3 Results and Validation

Figure 1 shows typical instantaneous droplet motion and streamwise velocity contour plot. The particle size represents droplet diameter. A dominant factor of injected droplet motion is not flow field velocity but injection velocity firstly, however droplets are followed to local flow velocity elapse of the time because droplet velocity are decayed by the drag force and droplet diameter gets smaller by vaporization (decreases the particle Reynolds number). Furthermore, droplet is fully vaporized in approximately 0.01 second.

In Fig.2, the statistical (in time & tangential direction) averaged streamwise velocity components at 17.6mm downstream of the inlet nozzle exit are shown. In this figure, a peak value of velocity and a reversed flow profile agree well with experimental data. And axial velocity profile peaks deviation which is one of the important characteristics in swirling flow is also well predicted. In Fig.3, axial velocity component of droplets is presented. For each results, droplet velocity is decayed, and spread to radial direction. Unfortunately, decaying rate and spreading rate is not agree with experiment, because initial droplet diameter set to 30 microns in this computation. In addition, considering various size of droplets are still undergoing.

4 Conclusions

LES of turbulent vaporizing spray by using Eulerian/Lagrangian approach has been carried out. The numerical results agree well with the experimental results such as air flow velocity components. Droplet velocity decay and spread is observed by this computation, however, decaying rate and spreading rate is not agree with experiment. To resolve this problem is still undergoing.

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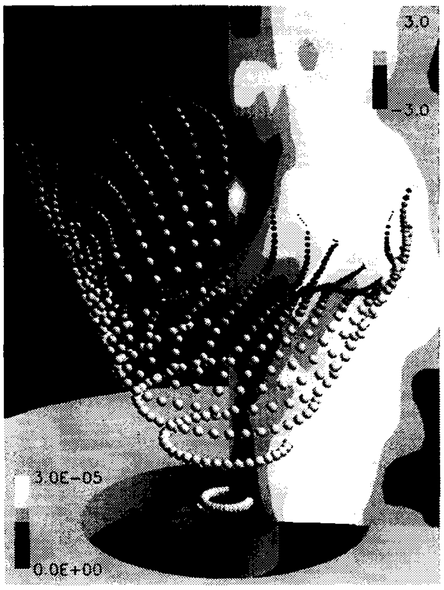

Figure 1: Typical instantaneous view of droplet motion and streamwise velocity contour plot

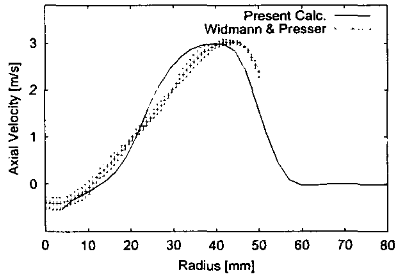

Figure 2: Radial profiles of the axial velocity component compared with experimental result

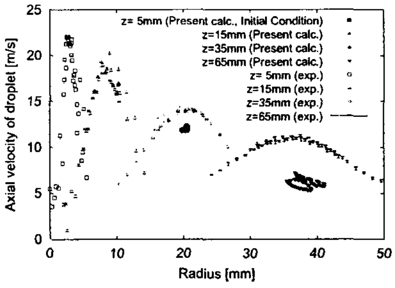

Figure 3: Axial velocity components of droplets