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NUMERICAL SIMULATIONS OF TWO-PHASE TURBULENT COMBUSTION IN SPRAY BURNERS

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ABSTRACT

The Complex interactions among turbulence, combustion and spray in realistic combustion systems (e.g. a spray-controlled swirl burner) is modeled and simulated via a new two-phase Lagrangian-Eulerian-Lagrangian large eddy simulation (LES) methodology. The spray is modeled with Lagrangian model which allows two-way mass, momentum and energy coupling between phases. The subgrid gas-liquid combustion is based on the two-phase filtered mass density function (FMDF) method that has several advantages over conventional methods. The LES/FMDF is employed in conjunction with non-equilibrium and equilibrium reaction models and reduced and detailed chemical kinetics mechanisms. LES of turbulent combustion in various flow configurations are conducted and generated results are compared with the available experimental data. The effects of spray, fuel type and composition, and inflow/outflow wall conditions on the combustion are investigated. It has been found that the main features of the turbulent flow and the flame inside combustor are modified by changing the flow conditions outside the combustor. The LES/FMDF results also confirm the significance of the fuel spray characteristics and the important role the spray may play in controlling the combustion.

INTRODUCTION

Advancing in the performance of the hydrocarbon-fueled combustors is a highly demanding issue that has attracted far-reaching research efforts for decades. The performance (efficiency, stability and compactness) of combustor in advanced air-breathing propulsion systems is dependent on the coupled and complicated effects of various parameters such as the fuel spray, the fuel/chemisty, the geometry, and the input/output flow conditions. Normally, it is very difficult to predict the combustor behavior under various operating conditions and it is extremely costly and time demanding to develop/test a new system via direct (trial and error) experimentation. Very recently, we have developed a robust and affordable large eddy simulation (LES) methodology that can be used for prediction of multiphase combustion and unsteady turbulent flow in realistic configurations. The proposed LES methodology is based on a Lagrangian-Eulerian-Lagrangian numerical scheme [1] and has already been applied to high Reynolds number compressible turbulent reacting flows in a liquid-fuel spray-controlled dump combustor and double swirl spray burner. Fig. 1 shows various elements of our computational flow solver in a block diagram. The Eulerian gas-phase part of the solver is based on a generalized high-order multiblock finite-difference method that may be used for computation of compressible turbulent flows in complex geometries.

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