Investigation of Spray Combustion Phenomena with Swirl Flow

in a Lab-Scale Aircraft Gas Turbine Combustor

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Abstract

Low NOx emission gas turbine engines for small scale aircrafts have been required because of the growing concern about environmental issues. In order to develop low NOx emission gas turbine engines, it has been required to understand spray combustion phenomena in combustors of gas turbine engines. It is, however, difficult to clarify the underlying physics of spray combustion phenomena in actual combustors because of difficulties of measurements: Laser diagnostics require the light paths. The objective of this study is, therefore, to understand spray combustion phenomena in combustors of gas turbine engines. To understand the spray combustion phenomena, the experimental combustor to which the laser diagnostics is applicable is needed. In this study, the lab-scale experimental combustor with optical path, which simulates the primary combustion region of actual Rich-burn, Quick-quench, Lean-burn (RQL) type aircraft engines, has been developed and fabricated. The combustion chamber, which has three quartz windows, has been designed to simulate a unit section of the annular combustor. Kerosene/air spray combustion proceeds with double (inner and outer) co-swirl flow in the combustion chamber. The fuel nozzle supplies kerosene as liquid sheet and forms solid V-shaped spray cone with swirling air flow. This pre-filming nozzle is utilized in actual aircraft gas turbine combustors. In this paper, flame structure, combustion reaction region and spray region are visualized by direct photographs, chemiluminescence of OH*(Detecting wavelength: 310 nm) and Mie scattering from fuel droplets, respectively. The direct photographs of the flames are taken by digital camera. Images of OH* chemiluminescence and Mie scattering are captured by high-speed CCD camera. Two dimensional images of OH* chemiluminescence is obtained by using the inverse Abel transform. In addition, the axis distribution of gas temperature is measured by B-type thermocouple.

It is found from direct photographs and two dimensional images of OH* chemiluminescence that OH* chemiluminescence doesn't exist in the luminous flame. This result indicates that gaseous-phase combustion reaction doesn't occur in the luminous flame region, and this means that brightness of the luminous flame consists of incandescence of soot heated in the upstream combustion reaction region. The combustion reaction region expands to the downstream with decreasing the fuel flow rate and increasing the air flow rate. Decrease in the fuel flow rate and increase in the air flow rate make the fuel atomization effective because of increase in sheer stress between the gas phase and the liquid phase. Therefore, it can be assumed that small droplets formed by fine atomization moved along with the swirling flow. Both evaporation of those droplets and combustion reaction take place in downstream of the combustor. In fuel rich condition, it can be also assumed that oxygen is used up in the upstream and combustion reaction doesn't occur in the downstream. The gas temperature measured by B-type thermocouple indicates that the peak value in the combustion reaction region exists on the center axis. Two dimensional images of Mie scattering shows the spray region moves downstream with increasing the air flow rate. On the other hand, the spray region doesn't move with decreasing the fuel flow rate.

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