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Effects of Inlet Air Preheating on NOx Emissions from a Kerosene Fuelled Partially Premixed Injection Burner

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Extended Abstract

Emissions characteristics of two partially premixed injection burners consisting of a pressure swirl atomizer (Flow Number: 3.6 x 10^{-8} m^2) and concentric dual swirlers were investigated using a quartz flame tube of 90 mm diameter and 200 mm length with kerosene as the fuel at atmospheric pressure. They are the same in configurations except that a converging mid shroud was provided to one of the burners, Type-A, to separate the swirling air flow through the inner swirler from the one through the outer swirler before entering the combustion chamber. The vane angle of the outer swirler was 45 degrees while that of the inner swirler was either 40 or 50 degrees. Fuel was injected into the swirling air flow from the inner swirler and the resulting mixture merged with the outer co-swirling air at the burner exit in Type-A burner. In the other burner, Type-B, fuel was injected into the swirling flow formed in combination of both inner and outer swirlers. Air was electrically preheated from 453 to 753 K by a 100 degrees step and equivalence ratio was varied from about 0.5 to the blow-off limits and pressure loss was set at 3% throughout the present study. A digital camera and a camcorder were used to capture the global flame structure and a laser sheet Mie scattering was to probe the axial position from the burner exit in the combustor where the atomized fuel was vaporized. Droplet size distributions of the spray were measured by a laser diffraction spray analyzer. The values of SMD in the present study were estimated to be in a range from about 40 to 20 μm, decreasing with injection pressure or fuel flow rate. In Type-A burner, a flame was seen to originate from a ring-shaped base, corresponding to the conical sheath of the spray, positioned at about 20 mm from the exit of the burner and to develop in a conical shape. Visualization of sprays in the downstream of the nozzle exit by laser sheet illumination showed that, at the inlet air temperatures lower than about 723 K, fuel droplets in the spray were not completely vaporized upstream the flame but disappeared promptly in the flame front. In Type-B burner, a full conical flame with its apex very close to the exit of the burner was seen at the lower end of inlet air temperature. An increase in air preheating resulted in an appearance of another conical flame with a ring-shaped flame base surrounding the abovementioned full conical flame on the center axis. Very high combustion efficiencies were obtained for both burners. A comparison of the NOx emissions from the two burners showed that, at inlet air temperatures equal to or lower than 653K, Type-A burner emitted less NOx than Type-B burner regardless of vane angle. At the highest inlet air temperature of 753K, the opposite was the case for the inner swirler vane angle of 50 degrees. The NOx emissions of Type-B burner were higher for the vane angle of 50 degrees than for 40 degrees while there was no appreciable difference between the NOx emissions from Type-A and Type-B burners for the vane angle of 40 degrees.

Effects of inlet air temperature on NOx emissions were not simple though similar trends were confirmed between the results for both types of burners. Fuel vaporization and, therefore, premixing of fuel and air are more enhanced at higher inlet air temperatures. This favors the suppression of formation of fuel rich pockets that may lead to higher gas temperature and faster NO formation at lean conditions. An increase in inlet air temperature, on the other hand, leads to a higher flame temperature, resulting in a higher NOx formation. The NOx emissions level at a fixed equivalence ratio decreased to reach a minimum at a temperature between 600 and 650 K and then increased with increasing inlet air temperature. The NOx emissions level at a fixed equivalence ratio decreased to reach a minimum at a temperature between 600 and 650 K and then increased with increasing inlet air temperature. For an inlet air temperature of 650K, EINOx of about 0.2 g/kg-fuel were achieved with Type-A burner at gas temperature of 1700 K.