Effects of Dilution on the Combustion and Emission Characteristics of Kerosene Fuel

Abstract

In this present dissertation, numerical studies are carried out to study the effect of dilution in a recirculating non-premixed Kerosene fuel combustion. All numerical simulations are performed using Reynolds averaged Navier-Stokes approach. Liquid droplets are tracked using Discrete Phase Model (DPM). Non-premixed equilibrium combustion model with the Probability density function (PDF) is utilized to model the combustion process. Flame structure, lift off characteristics and droplet dynamics of kerosene spray flames in various co-flow conditions are computationally studied. Three different co-flow conditions are considered: cold flow, cold flow with N_2 dilution, and simultaneous preheating and dilution. The lift-off height as well as flame width is increased with increase in co-flow velocity and dilution. However, beyond a point the flame fails to sustain and blows out. Simultaneous dilution and preheating of co-flow case shows a stabilized flame and distributed reaction zone. Numerical analysis on the effect of steam dilution and high pressure on kerosene fuel swirl combustion is further carried out. The thermal intensity of 5.37 MW/m^3 with 21.1 kW thermal input is considered for the computational study. The chamber pressure and steam dilution in the oxidizer is varied from 1 to 20 atm and 0% to 20%, respectively. The addition of steam as a diluent enhances the oxidation rate of CO to CO_2. Chemical kinetic study is carried out to study the effect of diluents on the combustion chemistry of simpler fuels like methane as well as a single surrogate species of kerosene. For low operating pressure conditions, the GRI-3.0 mechanism gives an excellent prediction. Whereas, for applications like gas turbines and furnaces, Aramco-3.0 and Curran mechanisms can be adopted to give good results. The San Diego mechanism can be chosen for low computational facility purposes as it shows very good predictions for ignition delay and laminar flame speed computations. Experimental and numerical study is further carried out using a novel hybrid swirl combustor to analyze different recirculation modes in the combustor. The hybrid-swirl, formed from the tangential and central vane air swirl inlets, helps in achieving low and uniform temperature throughout and assists in flame anchoring.