Combustion Characteristics of Biogas Flame from Palm Oil Mill Effluent (POME) at Variable Equivalence Ratio

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Abstract:
The use of different fuels in unmodified engines requires a thorough understanding of the change of combustion characteristics that are introduced by the different fuel. In the present study, the combustion characteristics of biogas at different equivalence ratio through numerical analysis are studied. A non-premixed flame is simulated based on a lab scaled burner with methane as a fuel for validation purpose. The turbulent non-premixed combustion simulation was performed by using $k-\varepsilon$ turbulence model coupled with Steady Flamelet model integrated with GRI 2.11 detailed kinetic mechanism by using Probability Density Function (PDF) approach. Good agreement was achieved between the numerical prediction and experimental data where the temperature distribution in the axial and radial direction of the burner was reproduced quite well. The combustion simulation of POME biogas with 65% methane and 35% carbon dioxide composition at different equivalence ratio ranging from 0.1 to 0.7 was simulated at fixed power output of 8.5kW. The fuel-bound CO2 consumption dominates the unique change of CO2 in the near-burner region of biogas flame which has not been observed in non-premixed flame of hydrocarbon fuels. Due to the same CO2 content of biogas, the specific heat of the mixture reduces and results in higher maximum temperature and average temperature at the central axis and the outlet respectively compared to that of methane. Surprisingly, the high average temperature at the outlet of biogas flame produces low average NOx emission due to the reduction in the rate of NOx production by the high concentration of CO2 in the reactant . At equivalence ratio of 0.1 to 0.6, the fuel switch from methane to biogas at fixed power results in more than 40% reduction in NOx emission at the expanse of 25% increase in CO2 emission.

Keywords: CFD; Biogas; Methane; Flame; Combustion; NOx

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