Combustion Analysis of a Can Combustor with CH_4/NH_3 Blended Fuels for a Micro Gas Turbine

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On the issue of energy production and emission, as the reserves of fossil fuels are decreasing, the industry is looking for alternative fuels to replace fossil fuels. Hydrogen economy has been proposed to achieve low-carbon emission and using ammonia as a hydrogen carrier is promising, since ammonia is widely used in industry such as fertilizer, chemistry, and frozen food factories without increase of carbon emissions. However, due to its high ignition temperature, small flammable range, and low heating value comparing with hydrogen and other hydrocarbon fuels, maintaining stable combustion of ammonia is a big challenge. As a result, many researches attempt to use CH_4/NH_3 as a blended fuel to increase the possibility of combustion.

The objective of our research is to investigate the combustion performance of a can combustor using CH_4/NH_3 blended fuels for a micro gas turbine. Combustion simulation is conducted by the commercial CFD software ANSYS Fluent. The computational model consists of three-dimensional, Realizable k-ε model for turbulent flows and Presumed Probability Density Function for combustion process between CH_4/NH_3 and air. The flamelet is generated by detailed chemical kinetics from GRI 3.0, and several mechanisms developed by Mathieu, Tian and Otomo are also tested. The current study used total heat input and fuel mass flow rate as the parameters for different compositions of CH_4/NH_3 blended fuels. Combustion performance was evaluated by temperature distributions, pattern factor and emissions.

Results indicate the maximum flame temperature and the exit temperature significantly decline with increasing NH_3 mole fraction at constant fuel flow rate. The results from GRI 3.0 predict highest NO emissions comparing with others. It can be seen that when adding NH_3, NO emissions is increased, the more NH_3 content of the fuels, the more fuel-NO generated. When NH_3 mole fraction is larger than 0.6, High temperature zone becomes smaller and the flames cannot be stabilized in the primary zone, which requires design modification of the can combustor. To maintain a certain thermal loading of the combustor, the flow rate of CH_4/NH_3 blended fuel need to be increased. The fuel injection velocity is too high to sustain stable combustion in the primary zone. High temperature and high pattern factors at combustor require design modification of cooling strategy. The mole fraction of NO gradually increases with increasing NH_3 percentage except the results from Mathieu's mechanism, which remains about 400 ppm. Before CH_4/NH_3 blended fuels are utilized as an alternative fuel for the micro gas turbine, further experimental testing are needed as the CFD modeling results provide a guidance for the improved designs of the combustor.