Heat Exchanger (HEX) Combustor for Ultra Micro Gas Turbine

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Abstract

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In order to develop a micro combustor for Ultra Micro Gas Turbine Engine (UMGT) a micro combustor with an integrated heat exchanger, called HEX-Combustor, was proposed, prototyped and tested. HEX-Combustor was proposed to improve the combustion efficiency and to widen the flame stability by reducing the heat loss from the combustion zone and reducing the reaction time through increasing the reactants temperature. HEX-Combustor consists of a triple tube system; inner, middle and outer tubes. The reactants flow into the inner annulus and pass through a porous plate which is inserted across the inner tube to activate the formation of a thin flat- flame. Very intense combustion hence occurs in a small part of the inner tube. The high temperature gas thus produced will exit to the downstream turbines that are absent in the present rig setup. The exhaust gas from the turbines enters into the outer annulus, where heat recuperation occurs in the premixture reactants in the inner annulus. With this configuration, it is intended that the reactants are heated by the heat transfer from both the combustion products and the turbine exit gas. A prototyped HEX-Combustor with an inner tube diameter of 14 mm was experimentally tested in order to observe the combustion characteristics and the heat exchange mechanism of the HEX-Combustor. The experiments were performed under atmospheric pressure and room temperature. In the experiments a real turbine was not used, instead the

combustion products were directly re-circulated to the outer annulus, with the expectation of gaining a similar effect of heat transfer in the real operation. The exhaust gas measurements include the CO, unburned hydrocarbon and NO_X concentrations. The temperature measurements include the combustion products along the axial direction, reactants temperature at the inlet and exit of the inner annulus and simulated turbine exit gas temperature at the inlet and exit of the outer annulus. In the present experiments, stable flat-flame combustion was achieved with methane fuel at air mass flow rates up to 0.06 g/s in prototyped HEX-Combustor. Combustion efficiency of more than 99.85 % was achieved between the equivalence ratios of 0.6 and 0.85 at the air mass flow rate of 0.06 g/s. Improvement in the burning velocity and thus the reaction rate was achieved by the temperature increase of reactants, even though the heat exchange was much smaller than that of expected, because of larger heat loss in the additional parts, which were installed to the bottom of the HEX-Combustor to provide the recirculation of combustion products in order to simulate turbine exit gas. As a result, wider flame stability at higher mass flow rate was achieved by increasing the reactants temperature. The experimental results also showed that the heat loss from the combustion zone was kept to minimum because of the encapsulation of the combustion chamber. In addition to the investigation on combustion performance of the HEX-Combustor experimentally, the heat exchange mechanism was evaluated numerically.