Combustion-based Small-scale Micro-power Generation

Dr. Seyed Ehsan Hosseini (Assistant Professor of Mechanical Engineering)

1. Introduction

The miniaturization of electric power generation for running low weight mechanical devices has led micro-energy generation studies to the development of small-scale combustion systems. Considering moderately efficient energy conversion of small-scale combustion systems and hydrocarbon fuels, application of these devices instead of current widely used electrochemical cells would result in weight reduction and lifetime augmentation of the mechanical systems. Undoubtedly, the functionality of portable Micro-electro-mechanic-systems (MEMS) will be significantly improved by availability of high-performance small-scale power generators. Nevertheless, improvements in thermal and chemical management and proper diagnostic and control of the system would illustrate significant progress in the development of miniaturized combustion. As the volume of combustion system decreases to small-scale combustors, ignition and combustion stability are becoming considerable challenges due to short residence time and large heat loss. To overcome these shortages, several experimental investigations have been implemented in Combustion and Sustainable Energy Laboratory (ComSEL) at ATU to generate micro-power using both moving (micro-turbines) and non-moving (thermoelectric) systems. Although, the goal of both systems is to generate micro-power via combustion phenomenon, the approaches to the goal are different. Nevertheless, combustion instability and various shortages in burner and combustor have been noticed regardless of the micro-power generation method.

In this Conference application of small-scale combustion in micro-power generation using micro-turbine and thermoelectric systems was presented. The special focus of this work is on flame regimes, fuel/oxidizer mixing, flame stability conditions, heat recirculation, non-equilibrium transport, flame-wall thermal and kinetic couplings and improvement of energy conversion efficiency.

Mech Aero-2019 Conference is an international podium for presenting research about mechanical and aerospace engineering and exchanging thoughts about it and thus, contributes to the propagation of information. Mechanical Conference represents the huge area where the focus lies on developing product-related technologies with rapid advancement in research in recent years. Since Small-scale Micro-power Generation is one of the main researches in Micro-electro-mechanic-systems (MEMS), it has become one of the main researches in Combustion and Sustainable Energy Laboratory (ComSEL) at Arkansas Tech University (ATU), the principal investigator (PI) presented the results of this investigation in Mech Aero-2019 conference.

2. Summary of findings

This research is focused maximizing the power generated by a thermoelectric (TE) system coupled with a meso-scale vortex combustion chamber with thermal recupertaor. Initially, the effects of combustor geometry on the wall temperature and flame stability of two non-premixed (methane/air) meso-scale vortex combustors (symmetric/asymmetric) are tested. Then, the influences of thermal recuperator on the characteristics of a small-scale asymmetric combustor are evaluated. Finally, the TE system is used to generate micro-power and various aspects of this experiment are assessed. The TE system consisted of two 34mm by 30mm Peltier TE generators wired in series with one another and attached to the chamber walls to convert the heat dissipated by two walls of the chamber into electricity. Two different cooling systems (a fan-cooling system and a liquid-cooling system) were analyzed to determine which system could produce the most power. The fan-cooling system consisted of two aluminum heat sinks and a Stanley high velocity fan operated at 13.6m/s and 8.5m/s. The liquid-cooling system used was a COSAIR Hydro Series Liquid system that consisted of a 120mm cooling fan, heat exchanger, and water pump. While performing each experiment, the data collected included the temperature difference across each TEG, open-circuit voltage, load voltage and power generated. The results reveal that the stability of the flame in the asymmetric meso-scale combustor is more than symmetric combustion. In stoichiometric combustion when Reynolds number of combustion inlet air is 7822, the combustor wall temperature of asymmetric combustion is 100K more than symmetric combustion. Comparison between flame stability and wall temperature of the asymmetric combustion with/without thermal recuperator indicates that asymmetric combustor with thermal recuperation can provided stable combustion for TE power generation test. The experimental results of TE test determine that the maximum power generated was 0.72W with the liquid-cooling system at a maximum temperature difference of 104^{o}C at an efficiency of 0.35%.

3. Conclusions

Considering the positive effects of thermal recuperation on the combustion stability of an asymmetric vortex combustor, this system was employed as a heat source to generate power by TE. A TE system was designed to generate electricity by converting the heat dissipating from an asymmetric non-premixed meso-scale vortex combustion chamber. Two cooling systems were used to determine which method was more effective in maximizing the temperature difference and power produced by the TE. While performing the experiment, the temperature difference of each TE, the open-circuit, load voltage, current, and power were measured in order to analyze the TE system. It was determined that the water-cooling system produced the most amount of power generated, 0.72W, at a temperature difference of 104^{o}C. The power generated could then be used to power sensors and other electrical devices or charge a battery.

The conference was held on September 20,21 in San Francisco and the PI successfully presented the results of his work in this conference.