STEVENS Institute of Technology

STEVENS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF MECHANICAL ENGINEERING

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AN EXPERIMENTAL STUDY OF CATALYTIC AND NON-CATALYTIC REACTION IN HEAT RECIRCULATING REACTORS AND APPLICATIONS TO POWER GENERATION

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An experimental study of the performance of a Swiss roll heat exchanger and reactor was conducted, with emphasis on the extinction limits and comparison of results with and without Pt catalyst. At Re<40, the catalyst was required to sustain reaction; with the catalyst self-sustaining reaction could be obtained at Re less than 1. Both lean and rich extinction limits were extended with the catalyst, though rich limits were extended much further. At low Re, the lean extinction limit was rich of stoichiometric and rich limit had equivalence ratios 80 in some cases. Non-catalytic reaction generally occurred in a flameless mode near the center of the reactor. With or without catalyst, for sufficiently robust conditions, a visible flame would propagate out of the center, but this flame could only be re-centered with catalyst. Gas chromatography indicated that at low Re, CO and non-C_3H_8 hydrocarbons did not form. For higher Re, catalytic limits were slightly broader but had much lower limit temperatures. At sufficiently high Re, catalytic and gas-phase limits merged.

Experiments with titanium Swiss rolls have demonstrated reducing wall thermal conductivity and thickness leads to lower heat losses and therefore increases operating temperatures and extends flammability limits. By use of Pt catalysts, reaction of propane-air mixtures at temperatures 54ºC was sustained. Such low temperatures suggest that polymers may be employed as a reactor material. A polyimide reactor was built and survived prolonged testing at temperatures up to 500ºC. Polymer reactors may prove more practical for microscale devices due to their lower thermal conductivity and ease of manufacturing.

Since the ultimate goal of current efforts is to develop combustion driven power generation devices at MEMS like scales, a thermally self-sustaining miniature power generation device was developed utilizing a single-chamber solid-oxide-fuel-cell (SOFC) placed in a Swiss roll. With the single-chamber design, fuel/oxygen crossover due to cracking of seals via thermal cycling is irrelevant and coking on the anode is practically eliminated. SOFC power densities up to $420mW/cm^2$ were observed at low Re. These results suggest that single-chamber SOFC's integrated with heat-recirculating reactors may be a viable approach for small-scale power generation devices.

Dr. Jeongmin Ahn received a B.S. degree in Mechanical Engineering from the Rensselaer Polytechnic Institute, M.S. degree in Aerospace Engineering from the University of Michigan, and Ph.D. degree in Aerospace Engineering from the University of Southern California. He has extensive research experience in micro-scale combustion: design, build and test of a MEMS (Micro Electro Mechanical Systems), microscale combustor and power generator, catalytic combustion, heat recirculating combustor, single chamber solid oxide fuel cell, and thermal transpiration based propulsion and power generation.