Enhancement of hydrogen reaction in a meso-scale burner using innovative catalyst segmentation and cavity

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Abstract

A novel design concept for enhancement of hydrogen combustion in a meso-scale channel by using the combined effects of catalyst segmentation and cavities was proposed, and their effects and combustion characteristics are evaluated by experiment and numerical simulation with detailed heterogeneous and homogeneous chemistries. The objective of using catalyst segmentation and cavity in a micro-reactor is to integrate both advantages of the heterogeneous and homogeneous reactions to enhance fuel conversion and promote complete combustion in a confined distance. With a fixed total catalyst length (1.6 cm), the multi-segment catalyst reveals better performance than the single catalyst. The cavity offers a low-velocity shelter to stabilize gas reaction in high flow velocity and promotes homogeneous reactions in this region since the neighboring catalysts help to maintain a high wall temperature.

Motivation

In the miniaturizing process of combustor

- Heterogeneous reaction (surface reaction)
  - Advantages: Increase operation range, low combustion limit, high-conversion efficiency
  - Disadvantages: More expensive

- Homogeneous reaction (gas reaction)
  - Advantages: High energy densities
  - Disadvantages: Unstable combustion

To design a meso-scale burner to increase combustion efficiency and operation range.

Objective

Using catalyst segmentation and cavities in a meso-scale burner to investigate the effect of the H2 reaction property (hetero- and homogeneous reaction) in a meso-scale burner.

Experiment setup

- Material: Stainless steel
- Thermal coefficient (k): 16 ~ 19 W/m·K
- Length 82 mm
- Wide 25 mm
- High 5 mm
- Fuel inlet
- Outlet
- Alumina oxide (k = 20 W/m·K)

Results and discussion

--- Single catalyst

--- Catalyst segmentation and cavities

--- Catalyst segmentation


Conclusions

1. Use catalyst segmentation can extend hydrogen flame in straight channel.
2. The catalyst segmentation can help to maintain the wall temperature and reduce heat loss to the surroundings.
3. Cavities can maintain high temperature due to the heterogeneous reactions.
4. Etching localized cavities in a small-scale system can further stabilize the flame, and cavities can serve as the heat source for reactions.
5. Cavities can appreciably extend the stable operational range of the meso-scale burner for a wide variety of inlet flows.

These benefits of the proposed catalyst configuration can be applied in the design of a small-scale power/heating generator.