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Microscale Combustion: Progress and Challenges

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Abstract

Microcombustion-related research was mainly motivated by the development of micro heat engines to meet the demand for a new generation of micro power sources. Unlike conventional combustion, which takes place in macro-sized combustion chambers (centimeter scale and above), the flame stability in microcombustion is significantly influenced by intensive heat loss (thermal quenching) and destruction of active species (chemical quenching) at the gas-solid interface. To overcome the negative effects associated with the reduced combustor size (down to sub-millimeter scale), a better understanding of the heat transport in the microcombustion process is particularly important. This paper reviews recent developments in this area, focusing on the fundamental studies on the characteristics of microcombustion using analytical, numerical and experimental approaches. In particular, the progress made at the Department of Mechanical Engineering at NUS is more fully described. Employing a one-dimensional flame model, we investigate the flame temperature and entropy generation in the microscale combustion process. Based on this model and analysis, a set of microcombustion rules is proposed. Furthermore, the slip-wall boundary effects (velocity-slip and temperature-jump), which are typical in microfluidic devices, have been implemented in a numerical model to investigate their influence on the microscale combustion regime. The results show that the effects are negligible over the generic range of sizes of most microcombustors. Despite the difficulty of measuring the key parameters in the small confined space, the effects of operational conditions (fuel-air equivalence ratio and flow velocity) and structural parameters (combustor diameter, step height, wall thickness and combustor length) have been experimentally studied in a series of cylindrical combustors. The expansion-step design has been shown to be able to stabilize the flame across a wider range of velocities. Finally, we highlight opportunities for future work that might help to extend the application of microcombustion.