281f On the Stability of Micro-Scale Heat Sources

Niket Kaisare, Soumitra Deshmukh, and Dionisios G. Vlachos

Micro power sources have been proposed for a wide range of applications including portable heating for soldiers, driving micro-engines, as well as providing energy for endothermic reforming reactions for hydrogen production. Homogeneous or catalytic combustion of hydrocarbon fuels in micro-scale channels is being investigated due to the high energy density of these fuels. In conventional (macro-scale) systems, homogeneous combustion is predominantly used to generate heat [1]. This is primarily because of the slow catalytic reactions on the account of heat and mass transfer limitations. Conversely, catalytic reactions can be carried out in microreactors with milliseconds contact time, wherein the mass and heat transfer rates are high owing to the extremely small diameters. On the other hand, homogeneous combustion gets quenched in submillimeter channels through thermal and radical quenching mechanisms [2]. However, recently it was demonstrated that homogeneous combustion could be sustained in ceramic microchannels that were specially treated to prevent quenching [3].

The aim of this work is to provide a comparison between homogeneous and catalytic combustion of propane and to study their stability limits. The effect of the solid reactor body, the reactor dimensions, heat losses and operating conditions on the stability of self-sustained combustion are investigated. Norton and Vlachos [4] used two-dimensional computational fluid dynamic (2-D CFD) simulations to observe the effect of these parameters on the stability of homogeneous microflames. Since the resulting 2-D elliptic PDEs were solved using Fluent™, the process was computationally demanding. This paper, in essence, provides an extension of that work on homogeneous combustion as well as compares it with catalytic combustion. We use 1-D model to reduce the computational complexity in order to explore a larger parameter space. The validity of using a 1-D model is examined by benchmarking it against the 2-D CFD simulations. A detailed stability analysis for both catalytic and homogeneous combustion is presented. The two combustion models are contrasted in terms of ease of ignition, sustainability of the reactions and extinction characteristics. Based on this, design and operating guidelines are drawn.

References

[1] Fritz Ullmann (2002), *Ullman's Encyclopedia of Industrial Chemistry*, 6th edition, Wiley-VCH Verlag.

[2] Aghalayam P, and Vlachos DG (1998), Roles of thermal and radical quenching in emissions of wall-stabilized hydrogen flames, *AIChE J.*, 44, 2025-2034

[3] Miesse CM, Masel RI, Jensen CD, Shannon MA, Short M (2004), Submillimeter-scale combustion, *AIChE J.*, 50, 3206-3214

[4] Norton DG, and Vlachos DG (2004), A CFD study of propane/air microflame stability, *Combustion and Flame*, 138, 97-107