Non-uniform velocity profile mechanism for flame stabilization in a porous radiant burner

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Industrial processes where the heating of large surfaces is required lead to the possibility of using large surface porous radiant burners. This causes additional temperature uniformity problems, since it is increasingly difficult to evenly distribute the reactant mixture over a large burner surface while retaining its stability and keeping low pollutant emissions. In order to allow for larger surface area burners, a non-uniform velocity profile mechanism for flame stabilization in a porous radiant burner using a single large injection hole is proposed and analyzed for a double-layered burner operating in open and closed hot (laboratory-scale furnace, with temperature-controlled, isothermal walls) environments. In both environments, local mean temperatures within the porous medium have been measured. For lower reactant flow rate and ambient temperature the flame shape is conical and anchored at the rim of the injection hole. As the volumetric flow rate or furnace temperature is raised, the flame undergoes a transition to a plane flame stabilized near the external burner surface. However, the stability range envelope remains the same in both regimes.

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1. Introduction

Combustion in porous media has been recognized as a method that provides good flame stability, low pollutant emissions, extended lean flammability limit and high radiation efficiency. These features result from the enhanced internal heat recirculation by conduction and radiation within the porous matrix. The flame stabilization and the improvement of the radiation emission from the burner become important issues for the application of porous radiant burners where the radiant heating of a given load must be maximized, e.g., in paper drying [1]. In many applications also the burner must be continuously adjustable for operation at different powers, including the operation in confined heated environments, as those found in industrial furnaces, and, often, the burner must be designed for operation with different gaseous fuels. Besides, applications where the heating of large surfaces is required lead to the possibility of increasing the burner surface area in order to reduce the number of active controls, thus relying completely in passive control of combustion by the porous structure. The area enlargement causes additional temperature uniformity problems, since it is increasingly difficult to evenly distribute the reactant mixture over a large burner cross section avoiding both local flashback and blow-off over the entire surface while keeping low pollutant emissions.

Hardesty and Weinberg [2] studied the concept of heat recirculation in non-premixed combustion systems. In these systems, the heat from the recirculation is added to the chemical reaction energy and higher flame temperatures are achieved. In addition, the lean flammability limit can be extended by the high heat recirculation rates allowing the combustion of low calorific gaseous fuels [3]. Takeno and others [4–6] realized the advantage of enhancing the flame internal heat recirculation and developed a basic porous radiant burner (PRB) design. In their design, a high conductivity solid medium formed by cylinders was introduced axially across the flame region. This solid medium transferred heat from the post-flame region to the pre-heating flame region. Besides this internal heat recirculation, the authors also provided for external heat recovery from the combustion products to the incoming reactants. The enhanced internal and external heat recirculation resulted in flame temperature and speed higher than the values observed for one-dimensional unstretched laminar flames at the same reactant composition and temperature. Also, the results pointed that, for each set of power and equivalence ratio, there was only one position along the medium where the plane flames were stabilized. This suggested that the primary flame stabilization mechanism was a balance between the heat transferred from the downstream from the flame to the upstream from the flame. This is a purely heat transfer stabilization mechanism.