ESTIMATION OF RADIATION EFFICIENCY OF CYLINDRICAL POROUS REACTOR FOR COMBUSTION OF LEAN PREMIXED METHANE-AIR MIXTURE

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The process of combustion in porous medium allows generating more powerful radiative heat flux in comparison with combustion in open flame. In addition, combustion in a porous medium has a range of advantages, such as stabilization of the combustion wave at high combustion rates, the possibility of power regulation in a wide range, combustion of lean gas mixtures, and low NOx emission [1-3]. Radiative porous burners are a promising means for creating thermal radiation sources with controlled distribution of power, spectrum and radiation density. Such burners can potentially be used for non-contact heating of various materials in industrial processes instead of electrical heat sources. The purpose of the present study was to estimate the radiation efficiency of a cylindrical porous reactor developed by the authors during combustion of a lean premixed methane-air mixture.

The reactor consisted of two coaxial quartz tubes with outer diameters of 92 mm and 46 mm, and wall thickness of 3 mm. The space between the tubes was filled with zirconium dioxide balls with an average diameter of 2 mm for bottom 28 cm layer and 5 mm for 6 cm top layer. The outer surface of the cylindrical burner was covered by a double-layer thermal insulation consisting of a 1 mm stainless steel sheet (to reflect the radiative heat flux inside the porous medium) and a 25 mm Cerablanket high temperature fiber insulation. Premixed combustible mixture supplied from the bottom end, ignition of the mixture was carried out by an external source from the open top end. The combustion wave front propagated upstream the fresh mixture flow and stabilized at the boundary between balls of different diameters in a wide range of velocities and equivalence ratios. The flow calorimetry method was used to estimate the radiation flow inside the reactor. A 1 m long quartz tube was mounted in the center of the reactor along the symmetry axis, with K-type thermocouples at its ends; liquid moved inside the tube. The heat flux from the radiating porous medium was determined by the temperature difference between the cold and hot liquid.

A lean (ϕ=0.6) methane-air mixture was used as a combustible mixture in the experiments. The flow rate was maintained using pre-calibrated BRONKHORST gas mass flow rate regulators. The experiments were conducted in the range of mixture flow rates from 12.4 l/min to 74.4 l/min. It corresponds to mixture velocities at the burner inlet of 10-35 cm/sec. At lower flow rates the flame was extinguished and at higher flow rates the flame propagated downstream. To measure the heat flux received by water from the radiating porous medium, quartz tubes with an outer diameter from 5 to 25 mm, with a wall thickness of 1-3 mm were used. The measurements were conducted at different values of the mixture flow rate. During preliminary experiments it was found that the thermal flow obtained by water does not depend on the volume flow rate of the liquid. Radiative efficiency of the reactor was estimated as the ratio between heat flux obtained from calorimetric measurements and the thermal power of the burner. It was experimentally obtained that lower combustible mixture flow rate leads to the maximum radiative efficiency.

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