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Paper

Adiabatic Lean Combustion of Liquid Fuel Mist In a Hot Porous Solid

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Abstract

For an ultra lean mixture of liquid fuel (Kerosene) mist and air, adiabatic combustion technology was studied experimentally using a simple perforated cylindrical hot porous ceramic burner. During the steady lean combustion, high excess air ratios; 2.8 ~ 3.6 could be achieved through the range of fuel flow rate; 0.8 ~ 4 *g/min.* The emission levels of CO and NOx under the excess air ratios less than 2.0 were satisfactorily low. The effects of fuel flow rate on the emission levels were examined, and the mechanisms of flame confinement in the perforated cylindrical hot porous ceramic were discussed in detail. It was shown that the adiabatic combustion method of liquid fuel mist in a hot porous ceramics can be promising combustion technology for many applications owing to the ultra lean mixture condition, the strong light emission and the strong thermal radiation.

Introduction

From the point of view of the preservation of clean air environment and energy saving, many combustion studies have focused their attention on the development of technology for keeping exhaust burned gas clean. In particular, the technology for effective energy conversion by excess enthalpy combustion of lean flammable mixtures has been tried actively by some researchers using permeable solid since over twenty years ago. In the studies, thermal radiation characteristics due to the combustion in the hot porous media, and the propagation and stability of flame in a porous media have been examined experimentally and theoretically in detail [1−8]. We can see the excellent recent review by Howell et al. [5]. Many studies on the excess enthalpy combustion in the porous media, however, have focused their interests on the gaseous fuels, and few studies on the liquid fuels have been reported [1−4]. Kaplan and Hall [3] and Tseng and Howell [4] have reported recently experimental and theoretical studies on the combustion of liquid fuels in a porous radiant burner. The present study aims to challenge to the lean concentration limit of liquid fuel for the steady combustion in the light of the concept of the excess enthalpy combustion by hot porous solid, and to examine the combustion characteristics in detail.

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Apparatus and Procedure

Figure 1 shows the experimental setup. Liquid fuel (Kerosene) is transferred by magnet pump and vaporized in the heated cup (about 200 ℃). The mixture of vaporized fuel mist and air is transferred into the perforated cylindrical porous ceramic (Inner dia.; 20mm, Outer dia.; 50 mm, Length 110 mm, Porosity; 0.82 ~ 0.83, Mesh; 9 ~ 20, namely pore size; 2.8 ~ 1.3 mm). Then the mixture ejected from the surface of porous ceramic is ignited by a small pilot flame. With increase in the temperature of the heated porous ceramic after several minutes, distributed small flames formed on the surface regress into the hot porous ceramic owing to high heat flux from solid to the mixture. Thus, even an ultra lean combustible mixture can be burned steadily in the hot (and bright) porous ceramic.

The dependence of maximum excess air ratio on the

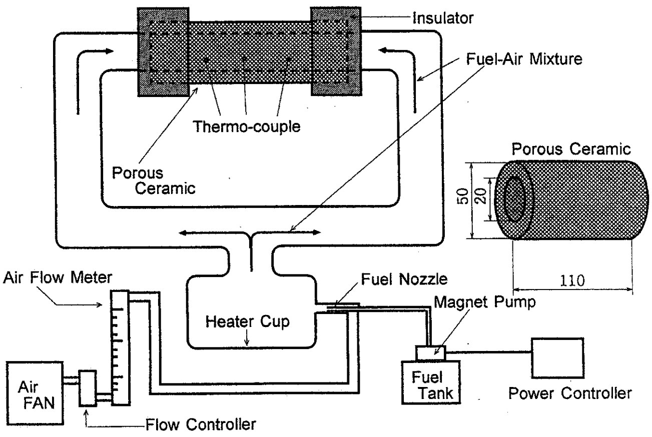

Figure 1: Experimental Setup

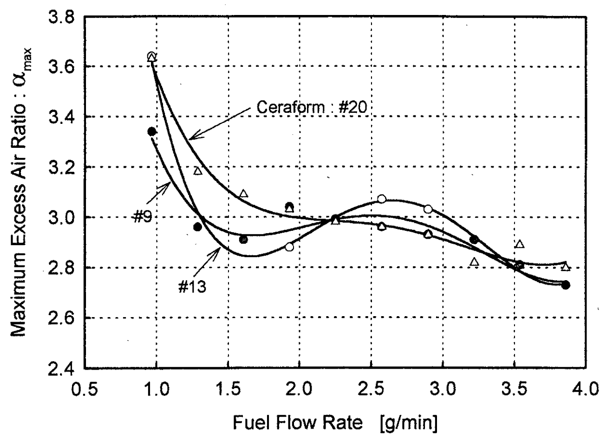

Figure 3: Dependence of Maximum Excess Air Ratio on the Fuel Flow Rate

fuel flow rate; 0.8 ~ 4 *g/min* (equivalent air flow rate; 9~46 *l/min*) was examined in detail. The temperatures in the hot porous ceramic were measured by R and K-type thermocouples. The emission levels in burned gas were measured by the constant potential electrolysis gas analyzer (Testoterm: GSV-350) with sampling probe at about 20 cm above the burner.

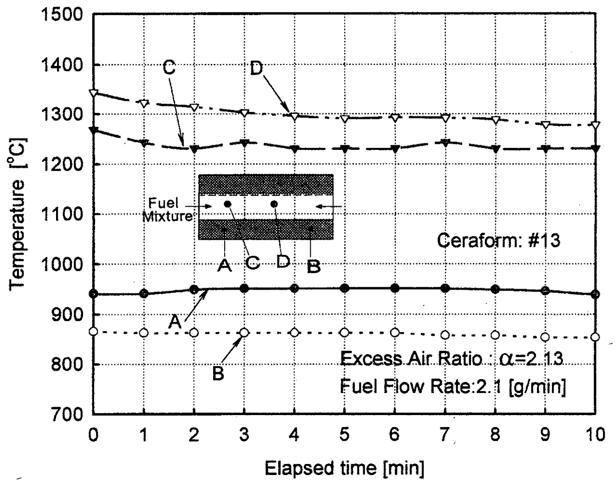

Figure 4: Temperatures in Hot Porous Ceramic during Combustion.

Results and Discussion

Figure 2 shows the direct photograph of the hot perforated cylindrical porous ceramic during steady combustion, where the flame is confined completely. We can see very strong light emission and thermal radiation.

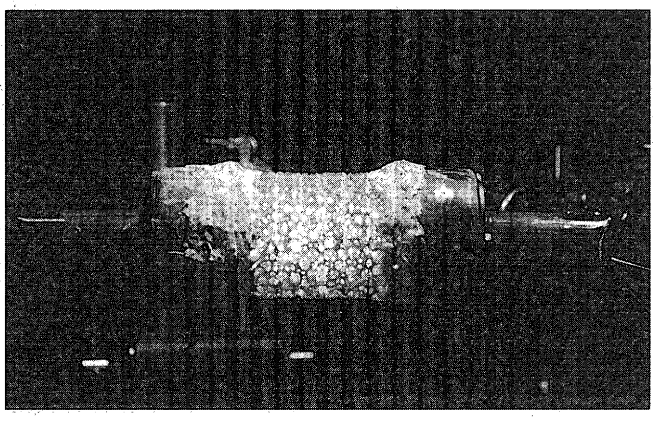

Figure 2: Direct Photograph of Hot Porous Ceramic Cylinder during Combustion.

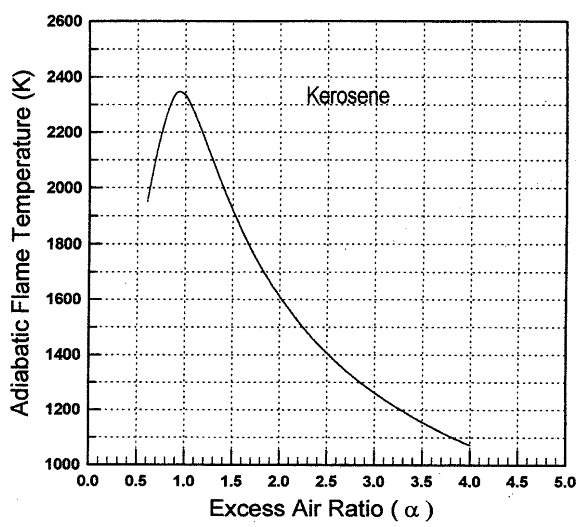

Figure 5: Calculated Adiabatic Flame Temperature of Kerosene.

The maximum excess air ratio for steady combustion attains 2.8~3.6 as shown in **Figure 3**, which is due to the successful ultra lean combustion of liquid fuel. Typical measured temperatures in the burner at high excess air ratio, shown as C and D in **Figure 4**, agree well with the calculated adiabatic flame temperatures of Kerosene shown in **Figure 5**. This is due to the high heat feedback from hot porous solid to the reaction zone, namely a kind of excess enthalpy combustion.

Why can the flame be confined in the hot porous ceramic? Using the calorific value of Kerosene; 10300 *Kcal/Kg,* fuel flow rate; 0.8～4 *g/min,* total inlet section area; 6.28 cm² and the equivalent air flow rate; 9～46 *l/min,* the inlet flow velocity of the mixture at the excess air ratio of 2.8 into the both ends of hot porous ceramic is estimated as 67～342 *cm/sec* approximately. This is very larger than the burning velocity of the lean mixtures of usual hydrocarbon fuels, and the flashback can not occur accordingly.

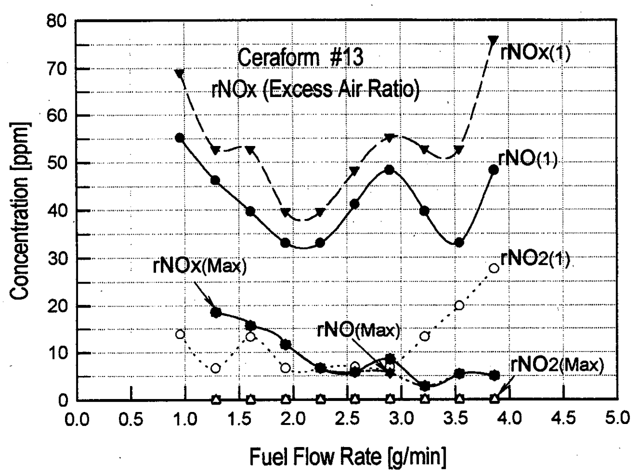

Figure 8: Dependence of Reduced NO, NO2 and NOx Emissions; rNO, rNO2, rNOx on The Fuel Flow Rate and Excess Air Ratio.

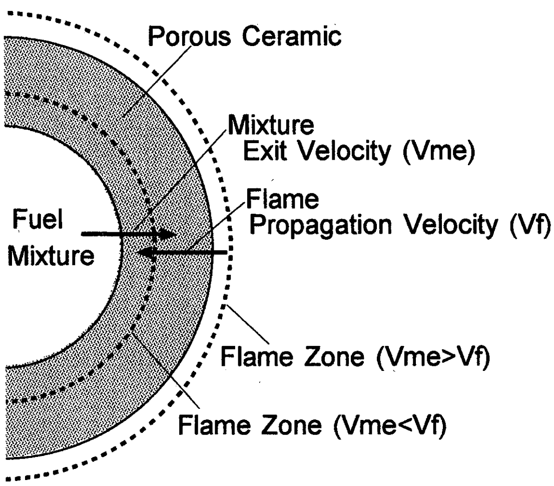

Figure 6: Schematic Model of Flame Position in the Perforated Porous Ceramic Cylinder.

In addition, as shown in **Figure 6**, owing to the porosity of 0.82 of tube wall and the large thermal expansion of gas mixture, the radial exit flow velocity of the mixture from inner tube-like wall is estimated as over 100 *cm/sec* at high excess air ratios. This is also the reason why the flame can be confined in the hot perforated cylindrical ceramic.

Typical dependence of the ratio; CO/CO_2 and reduced NOx in the emissions on the excess air ratio and fuel flow rate are shown in **Figures 7** and **8**. The emission levels were satisfactorily very low at the excess air ratio under about 2.0 through the range of fuel flow rates. This is due to the effective lean adiabatic combustion in the hot porous solid.

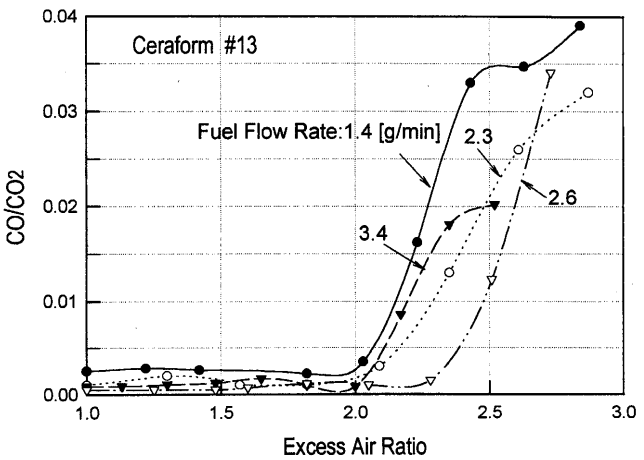

Figure 7: Effect of Excess Air Ratio on the Ratio; Emission CO/CO_2

Concluding Remarks

[1] Ultra lean adiabatic combustion at the excess air ratio over 3.0 for the mixture of liquid fuel mist is possible by using the perforated hot porous ceramics.

[2] The adiabatic combustion method of liquid fuel mist in a hot porous ceramics can be promising combustion technology for many applications owing to the ultra lean mixture condition, the strong light emission, and the strong thermal radiation.

[3] Successful reduction of CO and NOx in the emissions can be achieved under the excess air ratios less than 2.0, which is due to the effective excess enthalpy combustion of lean mixture in the hot porous solid.

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