



An Experimental Study on Flashback in a Ceramic Porous Burner

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ABSTRACT

Movement of flame in a ceramic porous burner with natural gas fuel is studied experimentally. Six thermocouples are mounted on the wall of the burner to track the flame. Flashback in a wide operating range in a single and double layers SiC porous burner is experimentally studied for the pore densities of 4 ppc and 8 ppc; equivalence ratios of 0.65, 0.75 and 0.85 and firing rates of 183-512 kw/m². The results are presented via temperature profiles in different times. Two cases were observed in flame moving. At the first case, flame moves rapidly to the beneath of the medium; while in the second one, flame gradually penetrates into the medium and thereafter moves beneath of it. In the second case, the flame penetrates at maximum 1 cm in porous medium at a velocity about 1 mm/s. In 4ppc pore density both cases where observed, but in 8 ppc the second case is soldom observed.

KEYWORDS

Porous Media, Combustion, Flashback, Firing Rate, Equivalence Ratio.

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1- BRIEF INTRODUCTION

In the past few years, porous burners are developed due to their advantages such as high radiation efficiency, low emission of NO_x, high flame speed, lower dimension of burner and ability to operate in low equivalence ratio. Stabilization of the flame is an important issue in the porous burners.

The difference between combustion in porous media and a conventional system arise because of better and efficient heat transfer from burned gases to unburned mixture. In conventional combustion system, the convection is the only mode of heat transfer (since gases have very low value of thermal conductivity and are radiatively less participating) from burned to unburned mixture. On the other hand, in porous media combustion, apart from convective heat transfer, the conduction and radiation modes of heat transfer are also significant. In addition, the convective heat transfer is also improved, on account of increased surface area within the porous matrix. There is a better homogenization of temperature across the porous matrix and the presence of significant amount of radiation helps to preheat the incoming air-fuel mixture upstream and thereby improve the combustion efficiency [1-3].

Shi et al. [4] studied low velocity combustion wave numerically and theoretically. They show that the most important control parameter affecting the combustion wave speed is the thermal capacity of the packed bed porous medium. Hashemi and Atoof [5] experimentally studied the effect of thickness and porosity of a metal porous media on the efficiency of the burner. They concluded that the increasing of firing rate and decreasing thickness, increase the radiant efficiency. Hashemi et al [6] investigated the effect of firing rate, pore density and equivalence ratio on the flame stability in a SiC porous medium and concluded that the increasing of firing rate, decreases the flame stability limits.

In this paper, flashback in a wide operating range in a single and double layers SiC porous burner is experimentally studied for the pore densities of 4 ppc and 8 ppc; equivalence ratios of 0.65, 0.75 and 0.85 and firing rates of 183-512 kw/m².

2- METHODOLOGY AND TEST DEVICE

In this study , the firing rate (FR) is expressed as follows :

$$FR = \frac{LHV \times \dot{m}_f}{A} \quad (1)$$

Where LHV, \dot{m}_f and A are the low heating value of the fuel (natural gas), mass flow rate of the feul and area of the burner, respectively.

Another factor is equivalence ratio is expressed as follows :

$$\phi = \frac{FA_a}{FA_s} \quad (2)$$

Where FA_a, \dot{m}_f and FA_s are the real fuel to air ratio

and stoichiometric fuel to air ratio respectively.

Six thermocouples are mounted on the wall of the burner to track the flame. The junction of thermocouples is in contact with the porous medium. The recorded temperatures are transmitted to a computer with a converter. The results are presented via temperature profiles in different times. Fig. 1 shows a schematic of experimental setup.

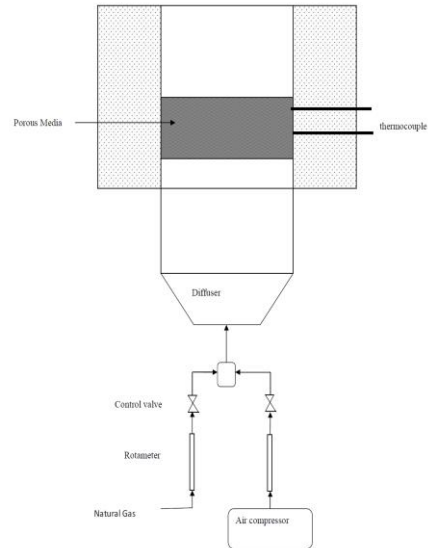


Fig 1: Schematic of experimental setup.

3- RESULTS

Temperature at the porous wall is recorded while the flow rates of fuel and air are adjusted so ten firing rates (183-512 kw/m²) and three equivalence ratios of 0.65, 0.75 and 0.85 are obtained. Tests are performed in the same initial temperature of 25°C. When flashback occurs, control valves are closed and data recording is stopped.

There are two cases of moving flame shown in Fig. 1. Position of the flame is at the maximum temperature location. At the first case (denoted as case 1), after startup, flame moves rapidly to the beneath of the medium. This case is called fast motion of the flame. In the second one (case 2); flame gradually penetrates into the medium and thereafter moves beneath of it. This process is called slow motion of the flame.

Table 1 shows case 1 and case 2 for pore density of 4 ppc and 8 ppc. It should be noted that in pore density of 8 ppc, at $\phi=0.65$ flashback does not occur and only at the firing rate of 512 kw/m² and $\phi=0.85$ case 2 occurs. In other conditions , fast motion of the flame is observed. In 4 ppc, both cases were observed in different FR and ϕ .

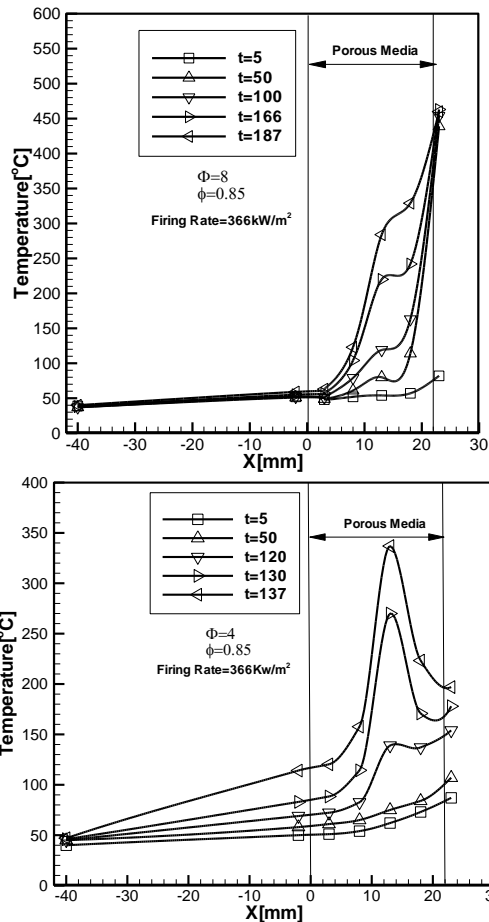


Fig 2: axial temperature for case 1 (Top side) and case 2 (Bottom side)

Table 1: Case 1 and case 2 in flame moving

Firin rate (kW/m ²)	4 ppc Equivalence ratio			8 ppc Equivalence ratio	
	0	0	0	0	0.85
	.65	.75	.85	.75	0.85
183	1	1	2	1	1
220	2	1	2	1	1
256	1	1	1	1	1
293	1	1	1	1	1
329	2	1	1	1	1
366	2	1	2	1	1
402	1	1	2	1	1
439	1	1	2	1	1
476	1	1	2	1	1
512	1	1	1	1	2

Fig. 3 shows the flash back velocity of flame in terms of firing rate for two equivalence ratios of 0.65 and 0.85. It can be observed that with increasing firing rate, the flame velocity for the equivalence ratio of 0.65, decreases. For the equivalence ratio of 0.85, the flash back velocity initially increases and then suddenly decreases.

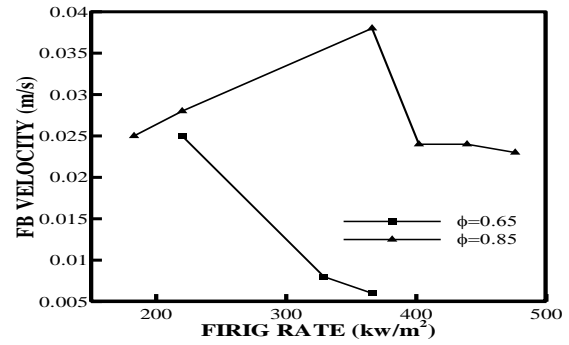


Fig 3: flash back velocity via firing rate

4- CONCLUSION

In this paper movement of flame in a ceramic porous burner with natural gas fuel is studied experimentally.

Two cases were observed in flame moving. At the first case, flame moves rapidly to the beneath of the medium; while in the second one, flame gradually penetrates into the medium and thereafter moves beneath of it. In the second case, the flame penetrates at maximum 1 cm in porous medium at a velocity about 1 mm/s. In 4ppc pore density both cases were observed, but in 8 ppc the second case is seldom observed.

5- REFERENCE

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