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Experimental Study of Premixed Flames Stabilization with Al_2O_3 Porous Media

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ABSTRACT: In the present research, stabilization of premixed flames with porous media is studied experimentally. First, for comparison, the effects of flame speed, equivalence ratio, and thermal power on the stability limit of a premixed free flame are investigated. Furthermore, the stabilization of the premixed flame with Al_2O_3 porous media is studied. Porous aluminum oxide ceramics with pore densities of 10, 20 and 30 ppm are used in the burner. Experiments are performed for 5 and 8 cm distances between the porous medium and the mixture outlet. The results show that the flame stability limit is independent of pore density and the flame is formed in the porous medium at all conditions at an equivalence ratio of about 0.55. Moreover the increase of porous medium distance from the burner causes the stability boundary in higher equivalence ratios. The amount of pollutants depend on distance and type of the porous medium. It is observed that the use of porous medium reduces NO_X and increases CO in comparison with the free flame burner.

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1- Introduction

Porous burners due to their special utilities such as higher combustion efficiency, lower pollution emission of NO_x due to low temperature of flame, lower burner dimension and larger flame propagation speed, are used in many branches such as industry food, powerhouses, residential and commercial places [1, 2]. In a free flame burner, heat transfer with convection of production combustion is done; while in a porous burner, moreover convection, radiation heat transfer has important role. The porous body has higher conductivity coefficient than gases. According to this, heat transfer at the low difference temperature up to ignition temperature is accomplished; in conclusion length of area combustion is increased and in this process, velocity flame and also range flammability is increased. The parameters such as the equivalence ratio, pressure, and pore geometry are affected in flame speed [3]. Important issue in premixed flame at porous burners is flame stabilization. Sathe et al. [4] theoritically and experimentally studied the stability and heat transfer characteristic of lean premixed methane-air flames in a porous burner. The results indicate that combustion is stable in in upstream half or in downstream edge region.
In this present study, premixed flames stabilization with SiC porous medium is experimentally studied.

2- Methodology

Test device is shown in Fig. 1. For reduction and fixation of air pressure, a regulator, for the hydrosol interception, a filter at path air and for air and gas flow measured, two rotameters are used with ranges proportional to the flows. According to information from the local gas company, the natural gas density is considered as 0.744 kg/m^3 and net heating value is about 35170 kJ/m^3.

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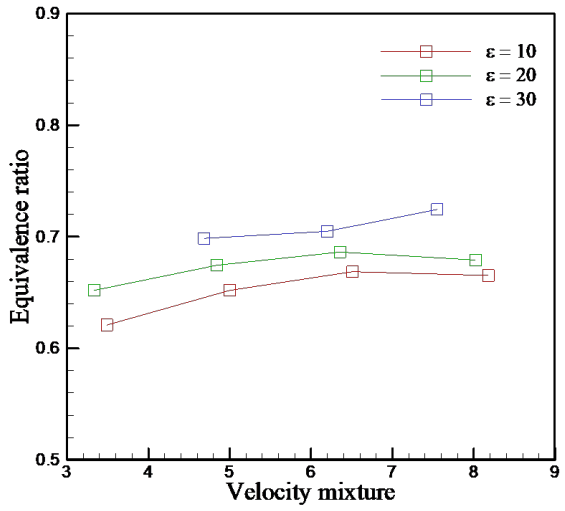
Figure 1. The device test

Device testo350 M/XL is used for measurement density dopant and flue temperature. This device has ability of density measurement dopant NO_x up to 3000 ppm, and dopant CO up to 10000 ppm. Also, thermocouple of this device has temperature tolerance ability up to 1200 °C.
For the experiments, premixed Bunsen burner is used. Sake interception of inter air surrounding to flame, burner is inter the combustor. Combustor is a cylinder with diameter of 22 cm and height of 100 cm. For observation of flames, frontward combustor, section is done with width of 7 cm and height of 22 cm. For reserve and displacement porous media of a conservator is used that can move at direction length and radius.
In the burner, a porous media of Al_2O_3 with cylinder form is used that is shown in Fig. 1. This porous media diameter is 90 mm, and height is 22 mm and also pores of 10 ppm, 20 ppm, and 30 ppm.

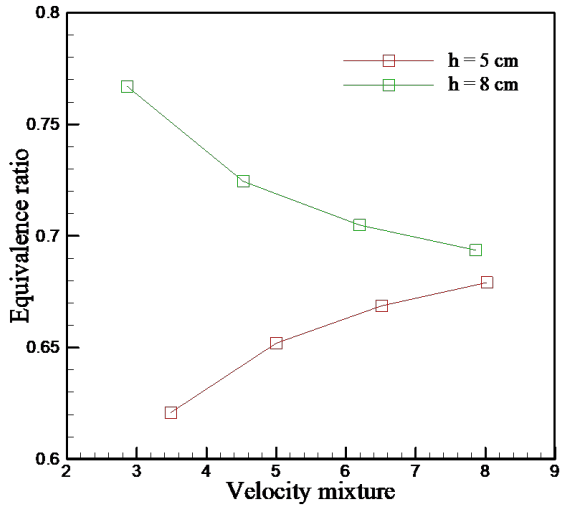
3- Results and Discussion

Effect of velocity mixture on equivalence ratio at difference porosities and heights, for flame entered to porous media

(case 2) is shown in Fig. 2. By increasing velocity of mixture, at the each three porosities, equivalence ratio is increasing by low slip.



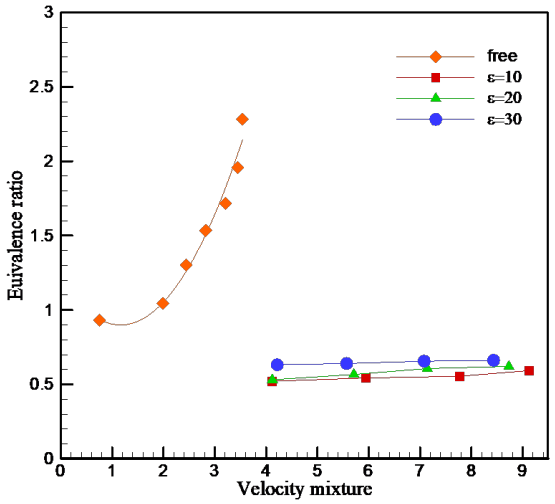
(a)



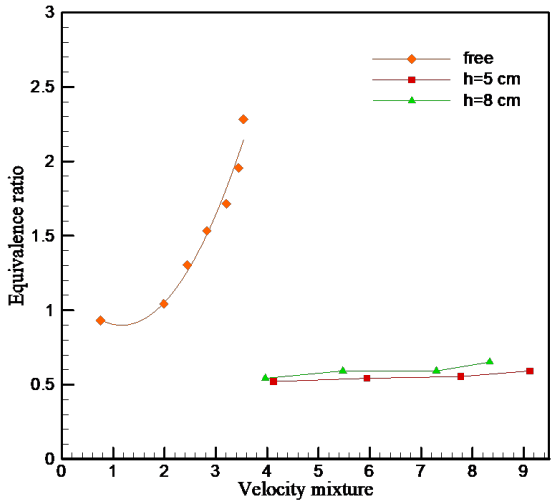
(b)

Figure 2. (a) Equivalence ratio vs. inlet mixture velocity at various pore densities for case 2 flame (b) Boundary of flame formation at porous medium with ε=10 and in two heights of the burner

Effects of pore density and distance of porous media on boundary stability for porous burner by Al_2O_3 porous media are shown in Fig. 3. Changes of the boundary stability at various porosities for h=5 cm porous media of burner with free flame burner, is shown in Fig. 3(a). In free flame burner range of equivalence ratio is $0.66<\varphi<1.63$ and limited stability is changed at $1.63<V_{mix}<5.06$ m/s. But in porous burner range of equivalence ratio is $\varphi<0.6$ and limited stability is changed at $4<V_{mix}<9$ m/s. Also it is observed that change density pore in porous burner does not have considerable effect on boundary stability. Change of the boundary stability at various heights is shown in Fig. 3(b). In porous burner, flame stability is at lower equivalence ratio, that this increasing limited flame stability.



(a)



(b)

Figure 3. (a) Stability limit at h=5 cm and various pore densities (b) Stability limit at ε=10 and various h

Changes of this dopants at various equivalence ratio, by ε=10, and at heights 5cm and 8 cm porous media of burner is showed in Table 1. According to results, use of the porous media in premixed burner compared to free flame burner, causes reduction of NO_x but density of generated CO is increasing. Reason for this changes is that, in a combustion reaction, fuel used at the process, firstly decomposes to CO and if reaction has sufficient energy, CO generates by available O_2 in reactant, then CO is generated [8].

In the free flame burner, flame has sufficient energy for changing CO to CO_2, but in porous burner, because flame accomplishes at porous burner, dissipation heat by porous media and reduced temperature production combustion, this reaction is not done. This process causes to increasing density of generated CO in the porous burner [6].

4- Conclusions

In this present study, premixed flames stabilization with SiC porous medium is experimentally studied. The results are as follows.

- The maximum of thermal power in free flame burner is

Table 1. Changes of dopants

	φ=0.82		φ=1.00	
	h=5 cm	*h*=8 cm	*h*=5 cm	h=8 cm
NO_x	4	8	8	8
CO	153	287	230	436
Tflue	160.3	172.1	170.4	273.2

PW= 3.2 kW

- By increasing porosities, (case 2) flame is accomplished at higher equivalence ratio
- Increased at the height and porosities has no considerable effect in stabilization flame
- By increasing porosities at the constant height (*h*=5 cm) flame is accomplished at the equivalence ratio of φ=0.58
- By increasing height at the constant porosities (ε=10) flame is accomplished at the equivalence ratio of φ=0.57.
- The value of dopant NO_x for the studied height of porous media from burner is lower than the value of this dopant in free flame burner

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