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Experimental Study of the Effect of Flame Holder Geometry on Flame Length and NO_x and CO Emissions in a Non-premixed Burner

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ABSTRACT: In this paper, the effect of different flame holder geometries on the flame length and NOx and CO emissions in a non-premixed burner are experimentally studied. A non-premixed burner with natural gas fuel and some cylindrical flame holder geometry with fixed outer diameter and different internal diameter and length are used. First, tests are carried out for the flame holders with the internal diameter of 4 and 6 cm and length of 10 cm and then for the flame holders with the length of 10, 15, and 20 cm and the internal diameter of 6 cm. The results show that by increasing the air flow rate, the flame length increases at a fixed thermal power and by increasing the thermal power, the flame length increases at a fixed-air flow rate. Moreover, it is indicated that any changes at the length and internal diameter of the flame holder does not affect the flame length, while it affects NOx and CO emission. Increasing the diameter of the flame holder decreases up to 42 percent of NOx and increases up to 40 percent CO.

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1- Introduction

Because the combustion is still the most common method of producing energy in many Industries, such as petrochemicals, food, steel, and ventilation systems, efforts have been made to improve the efficiency of the combustion equipment. One of these efforts is to improve flame stability and one of the most common methods to improve flame stability is to use flame holder. So far, many studies have been done on the effect of the application of the flame holders.

Hosokawa et al. [1] conducted a numerical study on the effects of flame holder shape on flame stability. They reported the rectangular section of flame holder increases flow stability behind the flame holder. Hashemi et al. [2] studied numerically the effect of the geometry of flame holder on the flame structure in non-premixed combustion. Their results showed that the change in the geometry of flame holder affects the pattern of recirculation zone and thereby reactive flow. In an experimental investigation by Hong et al. [3] the heat transfer characteristics of the flame holder on the onset of combustion instability were studied. Results indicate that with the ceramic flame holder, the appearance of the instability is delayed in time for some operating conditions. Hashemi and Jounaghani [4] experimentally studied the effect of a simple flame holder on the non-premixed flame stability. They showed that with increasing the length of the flame holder, the maximum temperature region moves toward the flame holder and hence the stability of the flame increases.

It can be seen in the most of the previous works, the effect of flame holder on the flame stability is considered while combustion emissions has not been studied empirically. For this reason, in this paper, the effects of the different flame holder geometry on the flame length and NO_x and CO emissions in a non-premixed burner is experimentally studied.

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2- Experimental Setup

In order to perform the experiments, a non-premixed burner has been designed and constructed. Also, three flame holder with inner diameters of 4 and 6 cm with a same length of 10 cm and the others with lengths of 10, 15 and 20 cm and the same inner diameter of 6 cm are used. The fuel is natural gas. Two different rotameters are used to measure flow rates of the gas and air. The testo 350 XL is used to measure the concentration and temperature of the exhaust gases. Fig. 1 shows the experimental setup used in this study.

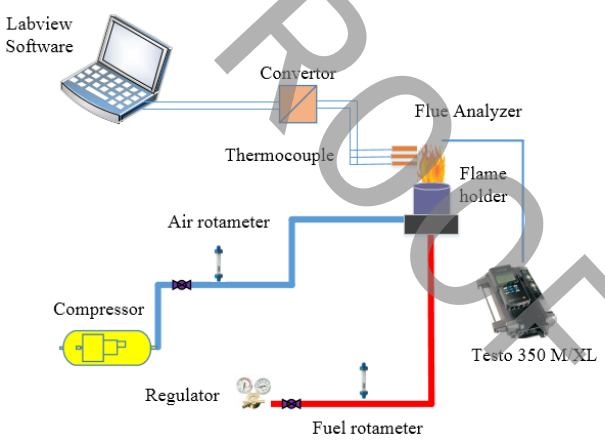

Fig. 1. Experimental equipment

3- Results and Discussion

In this section, the effect of changing inner diameter and length of the flame holder on the flame length and NO_x and CO emissions in a nan-premixed burner is investigated experimentally.

Fig. 2 shows the effect of flame holder length on the flame length. According to Fig. 3 at a fixed power, by increasing flame holder length, flame length does not change significantly. Therefore, it can be concluded that the change in flame holder length does not have a significant effect on the flame length.

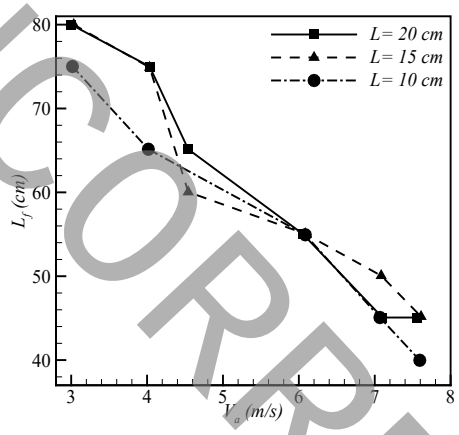

Fig. 2. Flame length versus inlet air velocity for different heights of flame holder at *P*=7.80 kW

Flame length for two inner diameters of the flame holder at a fixed length of flame holder is shown in Fig. 3. In this figure, flame length for two inner diameters of the flame holder is nearly similar, and only in low fuel velocities, the reduction of the inner diameter of the flame holder increases the flame length by 5%.

The effect of flame holder length on NO_x and CO emissions for 0.6 and 0.9 equivalence ratios are presented in Table 1. Note that the amount of NO_x for 10 and 15 cm lengths of flame holder is the same, whereas it becomes greater for 20 cm length of flame holder. For CO pollutant, it is observed that its amount was first reduced and then increased by increasing flame holder length.

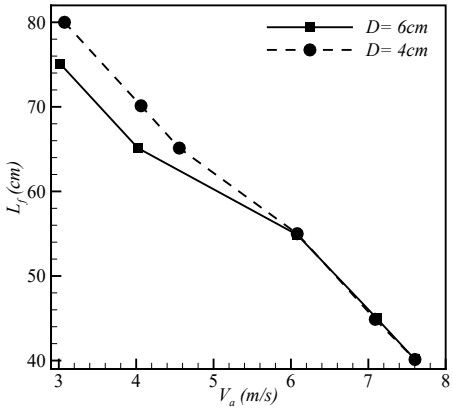

Fig. 3. Flame length versus inlet air velocity for different diameters of flame holder at *P*=7.80 kW

Table 1. NOx concentration, CO concentration and outlet gas temperature at *FR*=1725 kW/m² for different equivalence ratios and lengths

Results	*L* (cm)		
	10	15	20
		Φ=0.6	
NO_x (ppm)	9	9	11
CO (ppm)	593	530	549
T_0 (°C)	378.5	398.5	446.9
		Φ=0.9	
NO_x (ppm)	11	11	12
CO (ppm)	342	220	317
T_0 (°C)	401.2	416.3	467.1

Table 2 shows the effect of flame holder inner diameter on NO_x and CO emissions for 0.6 and 0.9 equivalence ratios. The results show that by increasing the inner diameter of the flame holder, NO_x emission decreases %38 for *Φ*=0.6 and %42 for *Φ*=0.9. Also, the CO emission increases in both reported equivalence ratio with increasing the inner diameter of the flame holder, which is consistent with the numerical results reported by Hashemi et al. [2].

Table 2. NOx concentration, CO concentration and outlet gas temperature at *FR*=1725 kW/m² for different equivalence ratios and diameters

Results	*D* (cm)	
	4	6
	Φ=0.6	
NO_x (ppm)	14	9
CO (ppm)	578	593
T_0 (°C)	437.8	446.9
	Φ=0.9	
NO_x (ppm)	19	11
CO (ppm)	246	342
T_0 (°C)	469.1	401.2

4- Conclusion

In this study, the effects of inner diameter and the length of a cylindrical flame holder on the flame length and NO_x and CO emissions in a non-premixed burner were investigated experimentally. Experimental results show that the flame length decreases with increasing inlet air velocity for a constant thermal power. Also, it is observed that changing the length and diameter of the flame holder in a constant thermal power does not have an important effect on the flame length. The result of the influence of the geometry of flame holder on the amount of pollutant production show that increasing the diameter of the flame holder decreases up to 42 percent of NO_x and increases up to 40 percent CO.

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