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Experimental Study of Stability of V-shaped Flame in a Premixed Swirl Burner

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ABSTRACT

In this work, stability of a V-shaped flame in a premixed swirl burner is studied. Effects of firing rate, equivalence ratio and axial velocity of fuel and air mixture on the stability of a V shaped flame is studied. For swirl generation, a 45^o angle swirler is used in the air inlet, which yields a flow with a swirl number of 0.78. Observations show that V-shaped flame is formed in a lean mixture of fuel and air. When firing rate increases, it is observed that flow velocity at V-flame formation instant is independent of flow rate and increases linearly from 1 m/s to 5 m/s. Flame lift off occurs in larger equivalence ratio and mixture velocity when firing rate increases. With increasing mixture velocity, flame quenching occurs in smaller equivalence ratios and larger firing rates. Hence, stability limit of V-flame increases with increasing cross section.

KEYWORDS:

Swirl Burner, Flame Stability, V-shaped Flame, Premixed Flame

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1- Introduction

Swirl flow is extensively used in combustion systems in order to mix reactants efficiently and stabilize the flame. Inlet swirl flow with a tangential component, creates a negative pressure gradient, inducing an internal recirculation zone. This recirculation zone moves hot products into unburned mixture and causes common conical flame to be a V-shaped. To better assess and classify swirl flows, a dimensionless parameter of swirl number is defined which divides the rotational flows into two categories: strong and weak [1]. Choi and Kim [2], in their experimental study have shown that swirl flames are stable in equivalence ratios from 0.57 to 1 and in equivalence ratios less than 0.5, flame does not occur. Thummers et al. [3] created a swirl flame and compared it to a conventional flame and concluded that swirl flame has a shorter length, more power and less pollution. Zhao et al. [4] studied performance of a premixed swirl burner and showed that thermal efficiency of a swirl flame is higher than that of the common one.

This experimental study examines the formation and extinction of V-shaped flame in a premixed swirl burner. The effects of some parameters such as axial outlet flow velocity, equivalence ratio and firing rate at the moment of formation, lift off and quenching of VSF are studied.

2- Test Devices

The measurement setup is shown in Figure 1. For air and gas flow measurement, two rotameters are used with ranges proportional to the flows, as shown in Figure1.

Figure 1. The measurement setup

A schematic of the used burner is shown in Figure 2. As shown, air enters its passage and after swirling mixed with the gas which enters the air stream radially (hollow arrows) from some ports on the gas pipe. The swirled mixture then enters conical zone and exits from the burner to form a swirling flame. The exit area of the mixture could be adjusted via turning the plug (gray portion).

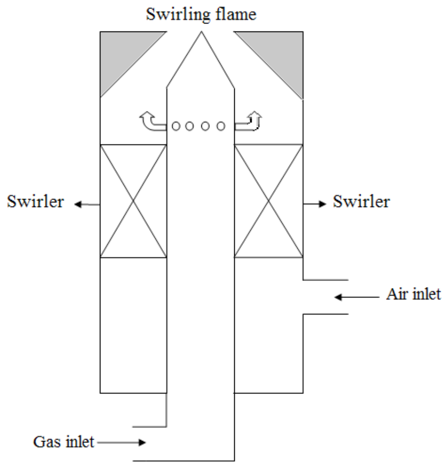

Figure 2. Schematic of the burner

Fuel and air flow rates and area of the inlet mixture are varied in the experiments. Parameters derived from these are: equivalence ratio, firing rate and axial velocity of the mixture which are defined as follows:

$$\emptyset = \frac{FAR}{FAR_{STO}} \quad (1)$$

$$FR = \frac{LHV \times Q_f}{A} \quad (2)$$

ϕ and FR are equivalence ratio and firing rate respectively. LHV is low heating value of the natural gas and Q_f is fuel flow rate. The natural gas density is considered 0.744 kg/m^3 and low heating value is about 35000 kJ/m^3.Tests are conducted at cross sections of 250, 280 and 310 mm^2.

3- Results

Figure 3 shows equivalence ratio vs. firing rate in the moment of VSF formation.

In all sections VSF is formed in a lean mixture. It must be noted that in the experiments air is increased so ϕ decreases until VSF is formed.

Axial velocity in VSF formation versus firing rate is shown in Figure 4. There is a linear relation between axial velocity and firing rate when VSF is formed. This figure shows that formation of VSF is determined by velocity of the mixture not its flow rate (each section area has a different flow rate).

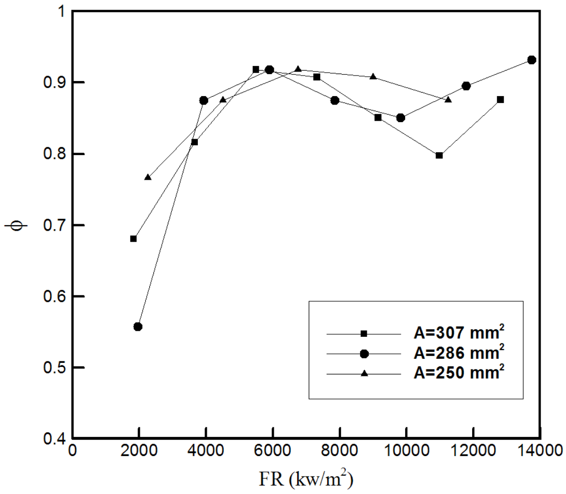

Figure 3. Equivalence ratio vs. firing rate in VSF formation

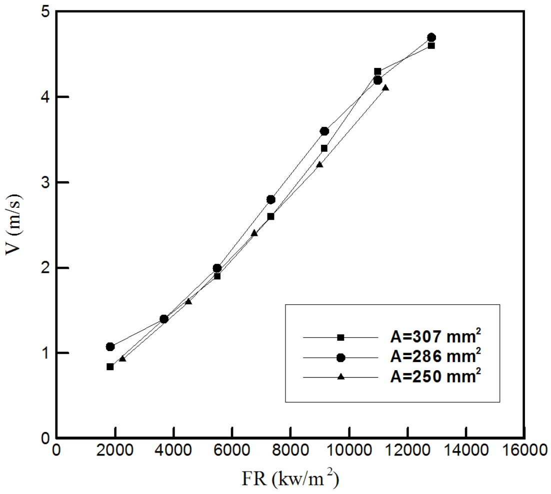

Figure 4. Axial velocity versus firing rate in VSF formation

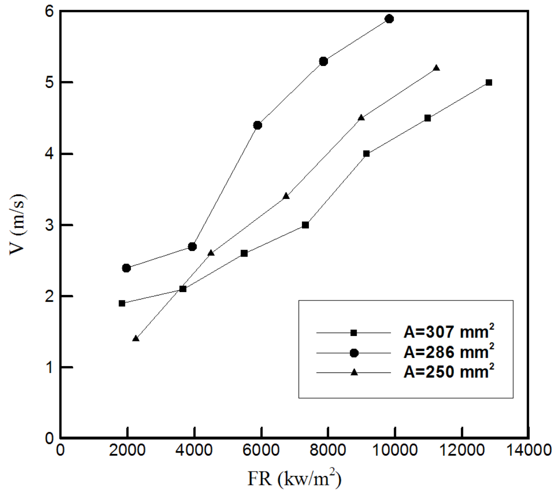

Figure 5. Axial velocity versus firing rate in VSF lift off

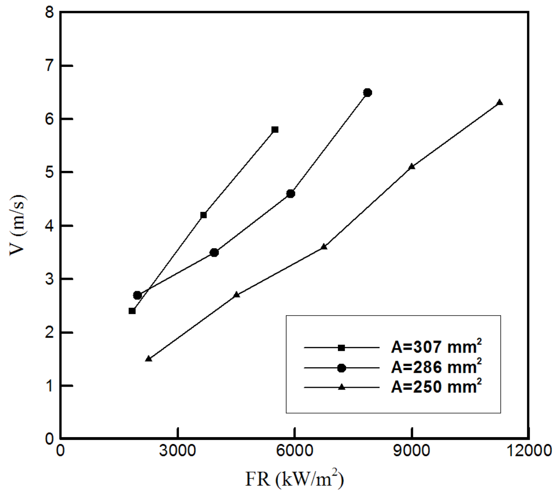

Figure 6. Axial velocity versus firing rate in quenching

Increasing air flow rate after VSF formation causes the flame to lift. Axial velocity in VSF lift off versus firing rate is shown in Figure 5. The velocities are above that of VSF formation but it depends on mixture flow rate.

Further increasing air flow rate causes the flame to be quenched. The velocity of the mixture in flame quenching is shown in Figure 6. It can be observed that also in quenching a linear relation is between velocity and firing rate.

4- Conclusions

In this study VSF is formed in lean fuel air mixture ($0.56<\phi<0.92$).

VSF formation is only a function of mixture velocity and firing rate and is independent of mixture flow rate.

Axial velocity versus firing rate in VSF lift off and quenching are a similar trend and depend on mixture flow rate.

5- References

[1] Beer,J.M., chigier,N.A., 1972. *"Combustion Aerodynamics"*. Applied science publishers Ltd.

[2] Choi. B., Kim. H. T., 2003. "Flame stability of CO/H2 syngas in the diffusion flame by using lab-scale burner". *Korean society of environmental Engineers*, 8, pp. 193-201.

[3] Thummers. M.J., hubner. A.W., Van reen. E.h. and Hanjalick. V.M., 2008. "Hysteresis and transition in swirling nonpremixed flames". *Cambustion and flame,* 256 (2), pp. 447-459.

[4] Zhao. Z., Yuen. D.W., Leung. C.W and Wong T.T., 2009 , "Thermal performance of a premixed impinging circular flame jet array with induced-swirl". *Applied Thermal Engineering*, 29, pp.159-166.