The Influence of Ring on AFR and Flame Height
Of Flame Lift-up Phenomenon; an Experimental Study

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Abstract

Employing Bunsen burner and a ring, this paper presents a flame lift-up phenomenon on propane combustion. The main objective is to present the influence of inside diameter of the ring and position of ring to Air Fuel Ratio (AFR) and also flame height of flame lift-up.

Three different inside diameter of rings made of stainless steel AISI 304 were investigated. It was found that inside diameter of ring effect the AFR for flame lift-up slightly. Position of ring and velocity of propane were more sensitive compare to inside diameter of ring on AFR flame lift-up. Inside diameter of ring and position of ring influenced the flame height very significant than AFR for flame lift-up happened. Flame height of flame lift-up do not equivalent to AFR. They follow an inverse function except on 10 mm inside diameter of ring and 30 mm position of ring which is flame height was the highest.

1. Introduction

Impairment of burner due to high temperature of flame comes about quite often. This comes up the idea to overcome this condition by shifting the flame to a certain distance from the burner. One approach that can be considered is flame lift-up.

Flame lift-up is a phenomenon that occurred when a ring is placed concentrically in flame above a Bunsen burner tube. On a certain Air Fuel Ratio (AFR) flame that formerly attach on the exit tube will jump to the ring and placed on the ring as it is shown on Figure.1. Initial research on propane flame lift-up has been done on a ring based on variation of air flow rate and position of ring from the burner [1].
premix flame height that developed by Rokke as presented on Eq. 1[3]:
\[
\frac{L}{d_0} = 33Y_f^{2/5}Fr^{1/5}
\]
(1)

where \(Y_f\) is mass fraction of fuel. Rokke experiment was conducted using propane in the range of mass fraction 0.15 to 1.0. The correlation was valid for \(Fr \leq 10^4\).

It also has been found that flame height on 30 mm position of ring and 10 mm inside diameter of ring was the highest. However the impact of geometric of ring has not been investigated. Blockage area of ring is considered as a prompt for recirculation zone [4]. Furthermore on ring stabilizer research that putting ring exactly on the exit burner has been found that gap of the ring increased the flame stability [5]. In term of the profile of flame holder, there was a study analyzing blow-off characteristic three different bluff bodies. Among them, rod seems more stable comparing to disk and cone. This result was achieved based on variation of upstream velocity modulation of gas [6].

This works however emphasize the effect of inside diameter of ring in associate to blockage area and position of ring on the impact of AFR for flame lift-up. In addition to bring this phenomenon practically implemented, the need for understanding flame length or flame height is also important. As a consequence effect of inside diameter and position of ring to flame height is also considered. Flame height of flame lift-up is described as the longest distance from exit tube burner to the flame tip.

2. Experimental Method

This research was carried out using propane as a fuel and a Bunsen Burner Flame Propagation and Stability Unit which consist of air flow meter and gas flow meter, fan and AC motor. The tube of Bunsen burner is 14 mm diameter and 38 cm height. A ring made of stainless steel AISI 304 with outside diameter of 30 mm and thickness of 5 mm was placed above the burner tube concentrically using a ring adjuster.

Variation of blockage area facilitated using three rings with constant outside diameter but vary on inside diameter. Three different inside diameter of ring which are 7 mm, 10 mm and 14 mm were investigated. Flow rate of propane and flow rate of air were measured using rotameter and recorded whenever lift-up happened. The rotameter had been calibrated using a wet gas meter.

Experimental was started with a ring that put above the exit tube burner concentrically using ring adjuster. Gas valve was open and it was kept on a fix value that can be seen from the rotameter. Ignition can be done and air valve was open slowly until lift-off. Then within a few second flames will jump from the exit tube burner to the ring and 'sit on the ring.

AFR was calculated based on regular propane flow rate. Air flow rate was regulated until the flame lift-up phenomenon came out. Air flow rate, flame height were recorded simultaneously. The height of flame was measured using a steel ruler and match up to average three images from a digital camera to calculate the mean flame height. Experimental set-up is shown on Figure 2.

Experiment was done on four positions of ring from the burner tube that is 10 mm, 20 mm, 30 mm and 40 mm respectively. For each position of ring, six variation of propane flow rate was carried out. The heat release of the flames studied ranges between 1.5 KW and 2.5 kW.

3. Result and discussion

The experiment results are presented on Figure 3 to Figure 6. Figure 3 and Figure 4 illustrates 4 graphics of AFR for lift-up and flame height as a variation of inside diameter of ring and propane velocity. Figure 5 and Figure 6 shows the AFR for lift-up and flame height as a variation of position of ring and propane velocity.

Figure 3 shows that on the same positions of ring, blockage areas do not give a major impact on AFR flame lift-up. On the same blockage area, higher velocities of propane decrease the AFR for lift-up. This result support the hypothesis that flame lift-up would appear due to momentum of air and fuel flow.

Figure 4 presents the flame height of flame lift-up. In term of inside diameter of ring, it looks that flame height is proportional to inside diameter of ring. The fact is that larger inside diameter or smaller blockage area will allow more mixture of air and fuels entrain the

Figure 2. Experimental set-up
Figure 3. AFR for lift-up

Figure 4. Flame height of propane lift-up
reaction zone. Bigger blockage area makes more mixture escape to the surrounding. However the interesting part is on 30 mm position of ring from the exit tube burner and 10 mm inside diameter of ring. On low velocity of propane indeed flame height is equivalent to inside diameter of ring. On higher velocity of propane the flame height is increasing sharply. Gap of the ring in this case is predicted to be the main reason [5] for this exclusion.

For the same blockage area and position of ring, flame height is also equivalent to the velocity of propane. This result meet the Rokke correlation in term of the Froude number will be higher [3]. In addition, this brings thermal diffusion as another internal stability factor which is associated to the rate of reaction would also have some bearing on flame height and flame speed.

If a comparison is made between Figure 3 and Figure 4 it clearly find that flame length is in the
opposite of AFR. Nevertheless alteration of AFR is on a smaller amount contrast to the alteration of flame length. It is agree with the previous result [2] and also Rokke correlation [3] in term of mass fraction of the fuel. The smaller AFR is equivalent to the greater mass fraction cum higher or longer flame height or flame length.

Completing the influenced of ring on flame lift-up phenomenon, effect position of ring to AFR and flame length are present on Figure 5 and Figure 6 respectively. Figure 5 demonstrates the increasing of position of ring will slightly decreasing AFR for lift-up. This is similar to the effect of inside diameter. However since the small alteration of AFR will give a huge alteration on flame length then it should be take into account on this analysis. This is the influenced of field flow of air and fuel that inhibit by blockage area of ring. Lower position of ring will make bigger blockage area. Therefore higher momentum flow is needed to overcome this barrier. As the flow of fuel has been kept constant consequently air flow rate must be increase to get higher momentum.

The same trend find on position of ring and inside diameter of ring in term of the effect of propane velocity on AFR. Greater propane velocity will decrease AFR for flame lift-up.

Figure 6 shows that correlation of ring position to flame height is difficult to declare. It seems blockage area as the result of inside diameter of ring and position of ring bear on this condition. Blockage area is not proportional to position of ring but inside diameter of ring. As a result flame length for 7 mm inside diameter and 14 mm inside diameter of ring are in the reverse trend. However as on Figure 3 the exception of flame height on 30 mm position of ring looks clearer. It means that on 30 mm position of ring and 10 mm inside diameter of ring give the smallest blockage area so that flame length becomes maximize.

4. Conclusion

The influence of inside diameter of ring and position of ring on propane flame lift-up has been present on the expression of AFR for flame lift-up and flame height. Both inside diameter of ring and position of ring slightly decrease AFR for flame lift-up. Inside diameter of ring is almost equivalent to flame lift-up except for 30 mm position of ring and 10 mm inside diameter of ring. AFR is very sensitive to the flame height and has a reverse function. Positions of ring and inside diameter of ring provide different impact on flame length. There is an optimum inside diameter of ring and position of ring that gives the best flame stability and the maximum flame height.

More mathematical analysis on the impact of inside diameter of ring is required as this is merely an experimental result. More over kinetic reaction and dynamic combustion of this phenomenon can be done in the future.

References