Flame Lift-up on A Bunsen Burner;  
A Preliminary Study

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Abstract
Some research on ring stabilizer for lean premixed turbulent flame has been done. In those researches the ring mounted flush with the exit burner port. This basic research also employed a ring which was incorporated above the tube by a ring adjuster. Propane and air flow rate were metered, mixed and introduced to the bottom of Bunsen burner tube. Propane flow rate kept unvarying and air flow rate was increased gradually. On some value of air flow rate, flame would jump to the ring and it did not attach to the exit tube any longer. This phenomenon was called flame lift-up.

This experiment was done on several variation of ring position. Air Fuel Ratios (AFR) for which the flame lift-up phenomena took place was calculated. Furthermore experiments without a ring have also conducted to compare the flame characteristic mainly the AFR for blow-off condition.

It was found that flame lift-up correlate interchange to the AFR. For the impact of ring position, it was found that there was a particular position that made flame lift-up stable very best. AFR for flame lift-up was in reversed to the position of the ring. Experiments without ring obtain that value of AFR for flame lift-up was above the blow off limit of flame without ring. In addition, from the Fudge diagram it was found that ring did operated as a flame stabilizer.

Keywords: Flame, lift-up, Bunsen, ring

I. INTRODUCTION

Understanding of the propagation and stability of premixed flames not only is important for fundamental combustion research but is also relevant to the development of new combustion technologies such as those associated with low-NOx emission, lean burn, micro-scale combustion, and material synthesis. In practical burners there are two important design criteria that are avoided, lift-off and flashback. Lift-off is the condition where the flame is not attached to the burner tube or port but it is stabilized at some distance from the port. Flash back is the occurrence when the flame enters and propagates through the burner tube without quenching. Flame lifting, as the result of lift-off condition, is generally unfavorable for a number of reasons. First it increases the escape of unburned gas or incomplete combustion. Secondly, above the lifting limit, ignition becomes intricate. Furthermore accurate control of the position of a lifted flame is difficult to manage so that it resulted in a poor heat transfer characteristic. Lifted flames can also be noisy [1].

However in some situations lifted flames are encouraged as it has been shown that lifted flames can reduce NOx levels in furnaces [2]. Damage on the nozzle tip of burner that had occurred very often also attracted the application of flame lifting. Concerning on flame stability of lean premix combustion, lift-off phenomena was took place at the most lean mixture. There are two mainstream researches on lift-off conditions: keeping the flame stable at lift-off condition and reattach the flame to the burner. Maintaining flame on lift-off condition was achieved by employ bluff-body, ring stabilizer etc [3-5]. Reattach the flame to the burner was achieved using a pulsed high voltage discharge [6]. This research was in the effort of maintaining the lift-off condition stable by introducing ring stabilizer. Research on ring stabilizer so far was putting a ring exactly on the tube of the burner [5]. This research was also using a ring that introduce above the Bunsen burner tube. This work however has to be considered as a first initiative.

A quite similar phenomenon with lift-off is introduced. As lift-off condition keeping the flame above the tube burner or port freely, this phenomenon was retained the lifted flame using ring. The occurrence when the flame jump to the ring was named lift-up. As a preliminary study, flame lift-up would be investigated on a Bunsen burner. The tube was 14 mm diameter and 38 cm height. A ring with outside diameter 30 mm, inside diameter 10 mm and thickness 6 mm was placed above the tube burner. Flow rate of fuel, in this case was propane and air was metered using rotameters whenever lift-up happened. The rotameter had been calibrated using a wet gas meter. 8 position of ring from the exit tube were investigated. Air Fuel Ratio and burning load was calculated than they were plotted on
graphics to get the Fuidge diagram. Understanding this phenomenon would inspire the application of flame lift-up in the future.

II. BASIC THEORY

There are many definitions of combustion. It involves fuel and oxidizer. **Fuel** is any substance that releases energy when oxidized. **Oxidizer** is any oxygen-containing substance that reacts with fuel for example air. Complete combustion can be achieved by mixing the fuel and the oxidizer. To characterize the fuel-air mixture some relevant relations are needed. **Air Fuel Ratio** or AFR is defined as [7]:

\[
AFR = \frac{m_{air}}{m_{fuel}} = \frac{M_{air}n_{air}}{M_{fuel}n_{fuel}}
\]  

It is expressed in terms of mass (m), molecular weight (M) and number of mol (n). The equivalence ratio of a air-fuel mixture is defined as

\[
\Phi = \frac{AFR_{stoichiometric}}{AFR_{actual}}
\]

One method to get cleaner combustion is lean combustion or \(\Phi<1\). Working with lean mixtures is advantageous from a pollution point of view as low flame temperature implies low potential for NO generation. However the flame may become too slow and hence prone to extinction or blow-off. Blow-off is the condition when the burning velocity is less than the mixture velocity. Simple design principle of the Bunsen burner has been incorporated in many gas appliances such as cooking stoves and gas burner. Premixed flame from Bunsen burners are relatively clean and give more intense combustion with higher effective temperature.

**Burning load (BL)** is defined as the power of combustion per area of burner. The equation for burning load is

\[
BL = \frac{V_{fuel} \times HV}{A}
\]

BL is burning load, W/m²  
\(V_f\) is fuel flowrate, m³/s  
HV is heating value of fuel, J/m³  
A is area of burner, m²

Flame will be unstable if the reactant flow rate is too high. This then results in the flame’s inability to maintain its position, and blow-off occurs. The entrainment of air from the surroundings will then weaken the mixture. Flame stability can be best described by a Fuidge diagram. Such a diagram is reproduced in Figure 1 [8].

Figure 1. Fuidge Diagram

III. EXPERIMENTAL RESULT

Flame lift-up phenomenon was initially discovered on ring stabilizer experiment. Ring was placed above the Bunsen burner tube. Fuel flow rate was fixed and air flow rate was varied until flame jumped from the exit tube to the ring and ‘sit’ on the ring as is shown on Figure 2.

This flame was completely different from the flame on Johnson, et al research. They put a ring exactly on the exit tube [5].

Figure 2. Flame lift-up on Bunsen Burner
Figure 3. Variation of AFR flame lift-up on ring position

Figure 4. AFR vs Burning Load flame lift-up
AFR and burning load when propane lift-up happened was calculated based on Equation 1 and Equation 3. The experiment result is presented on Figure 3 and Figure 4. AFR\textsubscript{st} by volume of propane or C\textsubscript{3}H\textsubscript{8} is 4.02 \[8\]. It means that the combustion was on lean combustion as the minimum AFR was around 40.

Figure 3 presents AFR of flame lift-up for each position of ring from the exit tube. 8 position of ring which were 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm and 40 mm from the exit tube were done. It is shown that the AFR for flame lift-up was depend on the position of the ring. As ring position is higher, the AFR decrease slightly. It means that flow rate of air must be higher to bring the flame ‘sit’ on the ring. Therefore flame lift-up is considered to be an equilibrium condition of burning and mixture velocity. Within the same position there was a certain range of AFR. Among the eight positions it was on 5 mm and 40 mm that lift-up found to be quite difficult. The wider AFR range implies that flame stability area was also wider. Ring position of 20 mm and 25 mm was the most stable among others. It indicates there are other reasons influence the lift-up phenomenon. It could be the turbulence and the separation flow of propane-air.

Figure 4 described the Fuidge diagram for lift-up flame. Compare to Fuidge diagram for methane \[7\], the AFR for propane was very much higher. Note that AFR\textsubscript{st} methane itself was around 10 and AFR\textsubscript{st} of propane was around 25 based on FAR 4.02 and 9.524 respectively. The lift-up curve was above blow-off curve without ring. In this condition ring was indeed considered as a flame stabilizer.

IV. CONCLUSION

As a preliminary study, the stability of flame lift-up phenomenon was investigated. It was found that lift-up will occur on lean combustion of premixed flame. From Fuidge Diagram flame, it was revealed that flame lift-up area is above blow-off area without ring. Position of ring has been discovered influenced very significant.

Further study on geometric of ring as a blockage area should be deliberated. Temperature between the exit tube and the ring becomes very striking to explore if this phenomenon will be implemented practically.

REFERENCES