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Investigation of Flame Characteristics of a Flameless Combustor Ignition System Using Direct Nozzle

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Abstract: In many industries, a combustor is used to generate heat to dry or shrinking the process. The ignition system for a combustor is necessary to make sure the flame can stay and generate heat during the process. The failure of ignition during firing up the flame during pre-heating is the problem that industry is facing is the main problem that need to be solved. So, the need to study flame characteristics using a direct nozzle is necessary to confront the problem This study has conducted an experiment using direct nozzle to study the flame characteristics and the maximum temperature. The result of this study shows that at an equivalence ratio of 1.67, the flame length is acceptable to be used in the combustion process. Besides, the flame temperature is steady along the experimental record time. As a result, the used of direct nozzle is not recommended because there is a little bit of flame lift of during the experiment. This experiment can be used to find a suitable nozzle for a combustor.

Keywords: Ignition, Flame, Direct nozzle

1. Introduction

In operating the hot air generator using conventional combustion, it generates high emission of pollutants such as Nitrogen oxides (NOx) and carbon monoxide (CO). The problem with burning fuels today is that pollutant emissions occur when burning those fuels and there is no uniformity of temperature profile produced during combustion. Flameless combustion was introduced to counter the problem of pollution when using hot air generators. Flameless oxidation (FLOX) also known as mild combustion, is a method that produces very low pollutant emissions, particularly thermal NOx and CO besides can help in ensuring optimum system thermal performance [1].

The prototype of the flameless combustion was successfully fabricated. After several tries in firing up the flame inside the combustion chamber, it was discovered that the combustor had a problem to firing up the flame during preheating. Thus, the study of the ignition systems and a characteristic of

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flame for a stable flame is required. The study is necessary to solve the ignition of the flame during preheating stage. This study will help to find a suitable solution in solving the ignition problem. Thus, combustion with a systematic ignition system will make sure the preheating process will surely be successful in making sure the flame is not extinguished.

1.1 Flameless combustion

To achieve flameless mode, the first step is the combustor must be heated up and the inside temperature of the combustion chamber should increase over the auto-ignition of biogas [2]. By lowering the temperature inside the combustion chamber to prevent reaching the thermal NOx formation temperature and reducing the dissociation of CO2 gas into CO in high-temperature conditions, flameless combustion can reduce NOx and CO emissions [3]. From these studies, we can understand the importance of better fuel mixing, higher exhaust gas recirculation, and longer companion time are all related to the ability to produce a homogeneous mixture that is essential for the generation of flameless mode.

1.2 Liquified Petroleum Gas

The demand for clean and cheap energy has become a global problem due to the depletion of fossil fuels and pollution. Compared to gasoline, LPG had a 4.5 percent decrease in cylinder pressure, and pollutants such as CO, HC, and NOx (nitrogen oxide) were reduced [4]. LPG can be considered as a clean combustion fuel because of the emissions reduction compared to biomass.

2. Materials and Methods

This study aimed to investigate the practicality and stabilizing a flame using a direct nozzle with the LPG and air as flammable supplies. This study will focus on the experimental study. The esearch study will be conducted in a few stages or phases as shown in Figure 1. The first stage in the study would be a literature review to find and understand the method, concept and technology involving combustion.

The next stages are the design experimental setup, procedure, and data collection instrumentation. Upon completing the drawing, several parts were fabricated according to the requirement on the drawing. The first initial firing up of the ignition system take place to test the experimental that have been setup.

After several real time experiments, and testing, data collection will be done by using the data collection instrument. The last stage are data acquisition and analysis will take place to continue to the thesis writing. The collected data will be analyses, present and explained thoroughly.

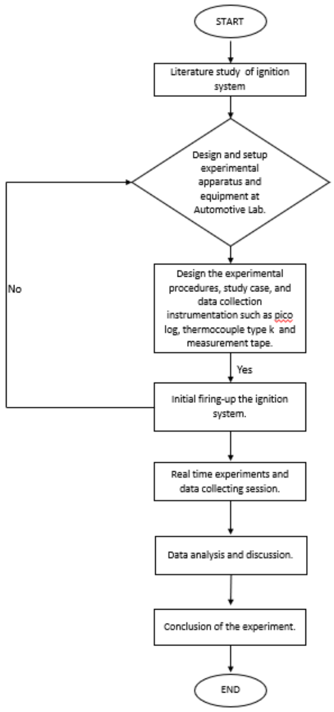

Figure 1: Research flow chart

2.1 Materials

The setup for the experimental study is listed below:

i. Air compressor as the air supply.
ii. LPG tank as the fuel supply.
iii. 5 type K thermocouples to collect temperature data in a range of -200 ℃ to 1200 ℃.
iv. Flow meter in the range of 3 l/min to 30 l/min and 0.1 l/min to 1.5 l/min.
v. Pressure gauges range from 0 psi to 210 psi.
vi. Measuring tape in centimeter

2.2 Methods

For this experimental study, the procedure must be implemented to ensure there is no problem when firing up the flame during pre-heat to supply. Firstly, the compressor and the LPG tank must be turn on to supply air and fuel to the direct injection inlet. In the premix experiment, 1 l/min of fuel and 5 l/min of air will be injected toward the direct injection inlet as being controlled and set by a flow meter. After that, a blowtorch is used to ignite air and fuel mixture. Then, as the fuel is constant at 1 l/min, the air will be set at 5 l/min, 10 l/min, 15 l/min, 20 l/min, 25 l/min and 30 l/min to observe the flame characteristics and temperature when the air is increasing.

2.3 Safety measure

During the experiments, several precautions must be considered to prevent incident occur during conducting the experiment while ensuring the safety of the researcher. Firstly, check the equipment condition before using the equipment is compulsory before running the experiment. This is important if the fuel supply system has any leakage will lead to serious injuries to the person nearby. The failed of any ignition must not exceed three attempts to avoid gas leaking to atmosphere. After completing the experiment, plug off the regulator on LPG tank supply for safety purpose. Another safety measures that must be included is putting and stand by a fire extinguisher in case of fire broke out happen. These safety measures are introduced to prevent explosion and fire during the experiment session.

There are also some laboratory safety practices that must be implemented for the safety measure. First, the gas supplies were stored in a separate tank to prevent explosions or fire broke out. Besides, smoke exhaust fans with ducts were installed in the lab to push toxic gases and smoke generated during the experiment outside the lab. Appropriate laboratory clothing such safety shoes, safety goggles and gloves must be worn before conducting the experiment. Lastly, to get an accurate and precise data, regular adjusting and calibration of the equipment such flow meter and thermocouple must be done.

3. Results and Discussion

The flame length is directly proportional to the equivalence ratio of the mixing fuel and air. If the air is sufficient, the flame length will not long and not short. Besides, the flame is crucial to make the chamber get a uniform heat through all space.

3.1 Results

The graph for the best flame characteristics using a direct nozzle is presented to show the result of the selections

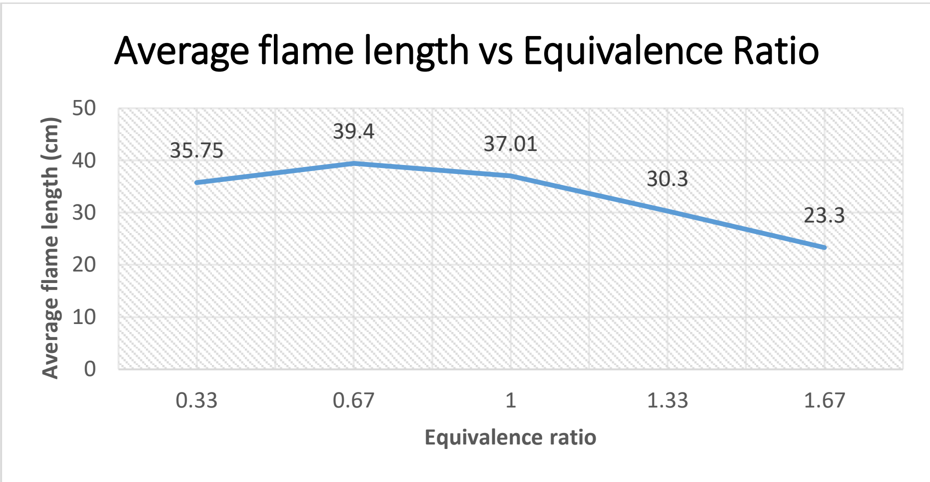

Figure 2: The average flame length over equivalence ratio

The Figure 2 shows the average of the flame length over the equivalence ratio. The flame length is gently increase from 0.33 equivalence ratio then decrease slowly when it touches 1 equivalence ratio. If the flame too lean, the length of the flame will become shorter than a blow off happen. This is because if the flame gets disturbed by the air velocity that make the flame cannot hold onto the fuel. So, the flame extinguished. The equivalence ratio 1.67 is the best flame for the direct nozzle because of the flame is not long and sufficient for small scale combustor.

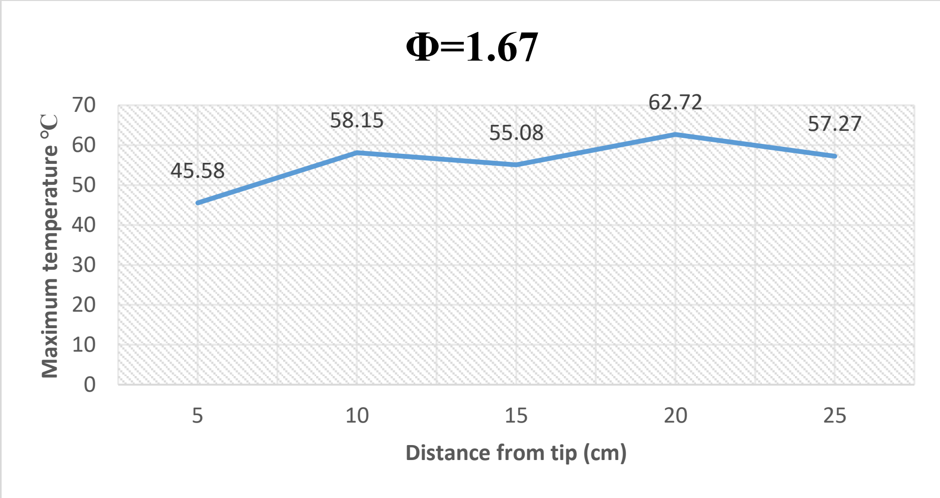

Figure 3: The maximum temperature over a distance when the equivalence ratio is 1.67

Figure 3 shows the maximum temperature when ER is 1.67. The graph is not fluctuated very much. The temperature is acceptable for combustion. This trend of the graph is what is needed to get a good and steady temperature profile. Thus, the flame produced is steady and the combustor will get the heat equally. So, there is less maintenence needed for the combustor.

4. Conclusion

The flame average length of the equivalence ratio 1.67 is 23.3cm from the tip of the direct nozzle. The maximum temperature for the equivalence ratio 1.67 also stable and not too much different than average temperature. Overall, the use of direct nozzle for flameless combustor ignition system is not recommended. using a wide range of flow meter or rotameter to get the maximum air supply in the reaction chamber. Fourth, future investigation can be performed for natural gas vehicles (NGV)/air mixtures with different hydrogen enrichment. Lastly, the use of smaller nozzle or a spiral nozzle to make the ignition system more efficient.

Acknowledgement

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Appendix A (Optional)

Any extra data, equations or information that is beneficial to the discussion of the paper should be included here. More appendices can be added as deemed necessary.

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