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The Effect of a Flame Holder Shape Modification Toward the Diffusion Flame Stability Zone Shift

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Abstract: The flame stability limit, which was involving the critical flow condition, lift off and blow out, could be affected by the burner geometry in the combustion system installation. Consequently a flame holder should be put in, to hold the flame as big as possible on a stable condition. The flame holder itself, is a device to hold the flame, whereas the flame holder could disturb the air and fuel flow. The fluid flow will be disturbed if the forces work on the fluid flow will be interrupting their stability. The fluid flow blockage by the flame holder will generate vortex and this vortex will end up with a turbulence condition. This turbulence condition will shift the critical stability limit and will produce a perfect combustion. In this research a concentric jet flow burner was implemented and the fluid flow speed and air speed was variated. To achive a perfect result, it is necessary to visualize the flow pattern using a schlieren photograph system. A thermocouple was introduce to measure the flame temperature and to know the temperature distribution. It is recocnized that a flame holder could be able to increase the flame stability zone. The hollow shaft flame holder was the one who could increase the stability zone significantly, because this kind of flame holder could hold the flame excellently and no lift off take place. The flame temperature distribution increase. The temperature increase has the smallest range compare with the combustion using the other kind of flame holders.

Key word: Flame holder % Stability limit % Concentric jet flow burner % Flow speed and air speed

INTRODUCTION

The flame limit stability was the operation limit of a combustion system. There were two kind of critical condition related to the flame stability, which is the flame lift off and the flame blow out. The critical flame limit stability depends on the burner geometry condition.

Wijayanti [1] studied the reactan flow mixing, it was found that a little increase of the fuel and air flow would release the flame from the burner port. Since this condition continued the combustion condition would go on a verry unstable phase.

On the test section a flame holder should be applied, because the critical condition of the stability is caused by the burner geometry. There were some flame holder models to hold the fire flame as big as possible and on a stable condition.

A Flame Holder is an instrument designed to hold the fire flame not easy to leave the burner port. The flame holder shape was designed into some models. The flame holder shape used on this research is a ring shape, a cone shape and a holow shaft shape. Actually, the flame holder is functioned as an obstacle or a flow obstruction. A fluid flow would be disturbe if forces works on the fluid was disturbe their stability. Flows colliding a flame holder will produce a small circulating flow and up with a turbulence flow.

To find out about the different flame patern, it is recomended to look the fuel and air flow patern implementing the schlieren photograph visualization system.

The research was conducted to find out how the shift of the diffusion flame stability zone moved because a flame holders attached and to find out how far these three kind of flame holders will influence the air and fuel mixing stabilizer. Furthermore, it is necessary, to know the flow patern visualitation caused by the flame holder attached.

Takahashi F. [2] conduct a research on a double concentric jet flow. In this research the flame diffusion turbulence was observed to know the flame turbulence structure. In more detail the research is trying to find out the influence of the swirl attached toward the flame structure.

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Rohmat T.A. [3] observe the diffusion flame stability on a hollow shaft attach inside a combustion chamber. This research was carried out inside an experimental kit which is connected to a wind tunnel with a low speed air flow. A porous plate burner was attached on the inlet experimental kit. The fuel used in this experiment is a 98% methane. From this experiment, it is found that there was a connection between the visual flame diffusion shape and the flame diffusion stability.

Another research on a double concentric jet flow burner was extended by Wijayanti, W. [4]. Wijayanti was trying to examine the diffusion flame visualization and the shifting of the flame stabilization zone. The result of this research was a Figure of a flame visualization, which was influence by the fuel flow speed, primer air, secondary air and the concentric annulus tube.

The Flame Diffusion Reactant Flow Structure: Several researches reporting that dynamic vortex always occur on the non-premixed flame flow structure, with an intention to stabilize the combustion process [5]. According to Marios [6], the reactant flow were dominated by the large scale vortex structure, because the reactant flow destabilization is passing through an amplification stabilization. The instability was influenced by the combustion temperature fluctuation and by the speed fluctuation. Takahashi, [2] from his research, said that the flame flow structure was strongly affecting the flow stability. The flow stabilizer were the vortices, which will dominate the combustion process.

There were two kinds of flow reactant mixing, which will be observed on this research. The first one was the unburned gas and the burned gas. Daily, [7] examine the flow structure of these two conditions. Which means that the combustion process did not induced the reactant flow mixing.

Physically, the flame lift mechanisme could be seen when the flame starts to leave the burner port. The flow transition goes to turbulence would be seen affecting the flame lift. For a good orifice, probably the flame woud flickering before the lift occure. The lift phenomenon could be clarified by looking at the diffusion process, the flow distribution, the speed distribution or the temperature. Every theory about the lift phenomenon were clarifying each other.

The blow out phenomenon could be interprated with the premix flame concept. Blow out would take place at a certain flow speed where the turbulence flame speed is higher then the local speed on the maximum flame speed position.

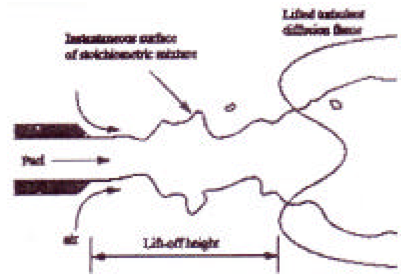


Fig. 1: Flame Difussion Lift

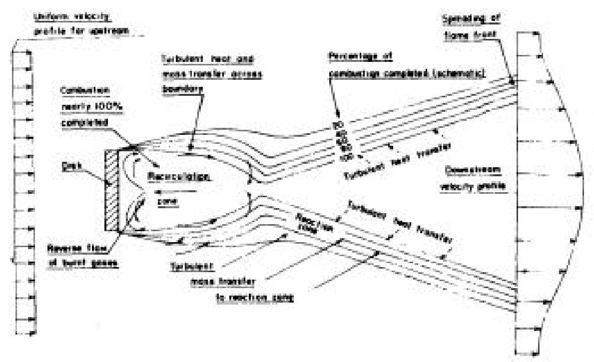


Fig. 2: Recirculation zone of a disc flame holder

Flame Holder: Flame holder is a device designed to hold the fire flame. The flame holder designed in this research has three kind of shapes. Fluid flow would be disturbed if the force working on the fluid is disturbing their stability. A flow which is disturbe by a flame holder will generate vortex, which ended with turbulence.

By adding a flame holder on this research, it is expected that the flow will be disturbe and the combustion process would be better and the fire flame would be much stable. Consequently the flame stabilization zone will be increase too.

Furthermore, on a fuel speed of over 40 cm/sec, the combustion stabilization would occur, so that the fire flame will be occur continuously. Some of the flame holder model could be attached on the nozzle tip ends.

The recirculation zone and the fire flame flow pattern with a disc flame holder could be seen on the Figure below.

Daily [7] mentioned, that the air and fuel mixing would strongly influenced the combustion stabilization. At an instabil condition, the occurance of the Kelvin-Helmhotz vortex will be verry important as a fluid steerer equipment on the mixing process. Flow mixing occur on the boundary layer zone, as a result of the temperature gradient involve at that area. This occasion was demonstrated on a flow pattern visualization and was supported by some researcher opinian, such as

Jaronsinski [8] and Norimatsu [9]. Both of them says that the flow pattern was strongly affected by the temperature gradient and the flow density.

It was known that the flow pattern was strongly affected by the flow density. Weinstein [10], said that the schlieren methode was an appropriate optical methode used to distinguish the flow.

RESEARCH METHOD

The method used in this research was an experimental research. The research kit were made in a laboratorium scale.

There were two variables used in this research. First was the free variables, which were the axial speed of air flow (U) with a value of 0 - 5 m/sec, the flame holder shape o-ring, cone and hollow shaft and the flame holder position from the burner end, with a variation of 2 mm, 4 mm and 6 mm. Second, were the fixed variables which were the gas axial speed at the lift off condition, the flame temperature and last was the air and fuel flow visualization.

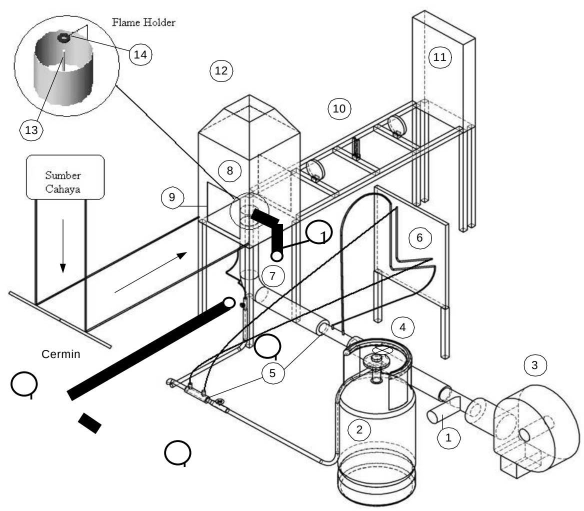
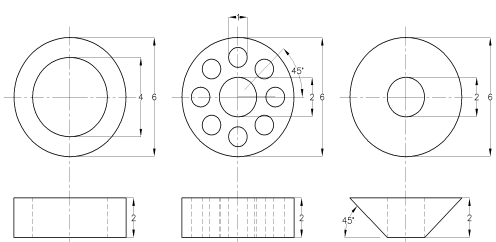


Fig. 3: Experimental equipment



(a) o-ring (b) hollow shaft (c) cone

Fig. 4: Flame Holder Shape

The Research Procedure: Liquid Petroleum Gas (LPG) was the fuel used in this research. The combustion chamber used in this experiment was a coflow burner system. The flame holder with three shapes types of o-ring, hollow shaft and cone should be placed on the one end of the chamber. The installation could be seen on Figure 3.

To observe the flame condition, a pirex glass window of 30 cm x 30 cm was fixed. This glass window was functioned either for observing the flame condition, or as a hole for a camera taking pictures. The flow pattern visualitation on this research was on the burned gas condition. Thermocouples were conected to an ADC and the data could recorded in the computer.

RESULTS AND DISCUSSION

Research Result: The data information obtain from the research were the flame temperature, the lift off and the blow out occurance, the flame temperature distribution on the flame vertical direction and datas about the flame flow pattern. The result from this research could be formulated as follows:

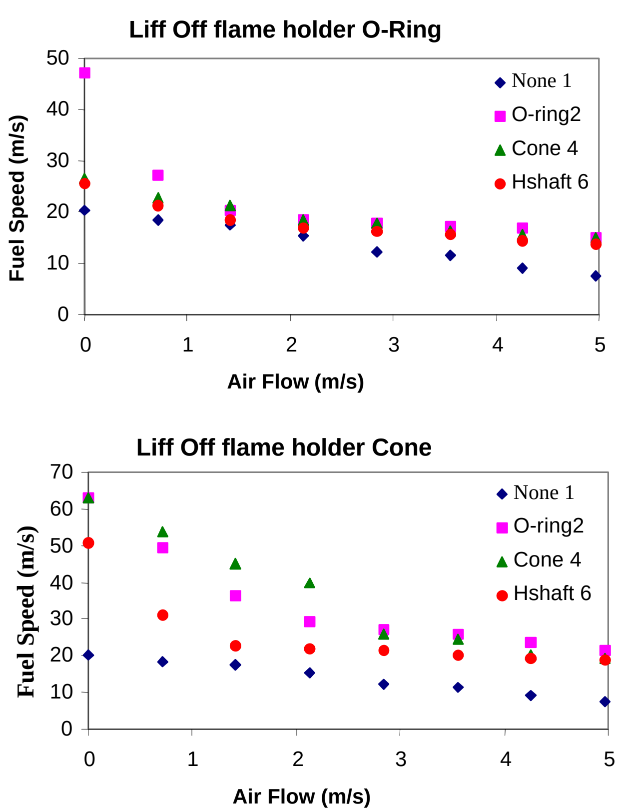


Fig. 5: Flame stability Diagram of a Flame Holder Model

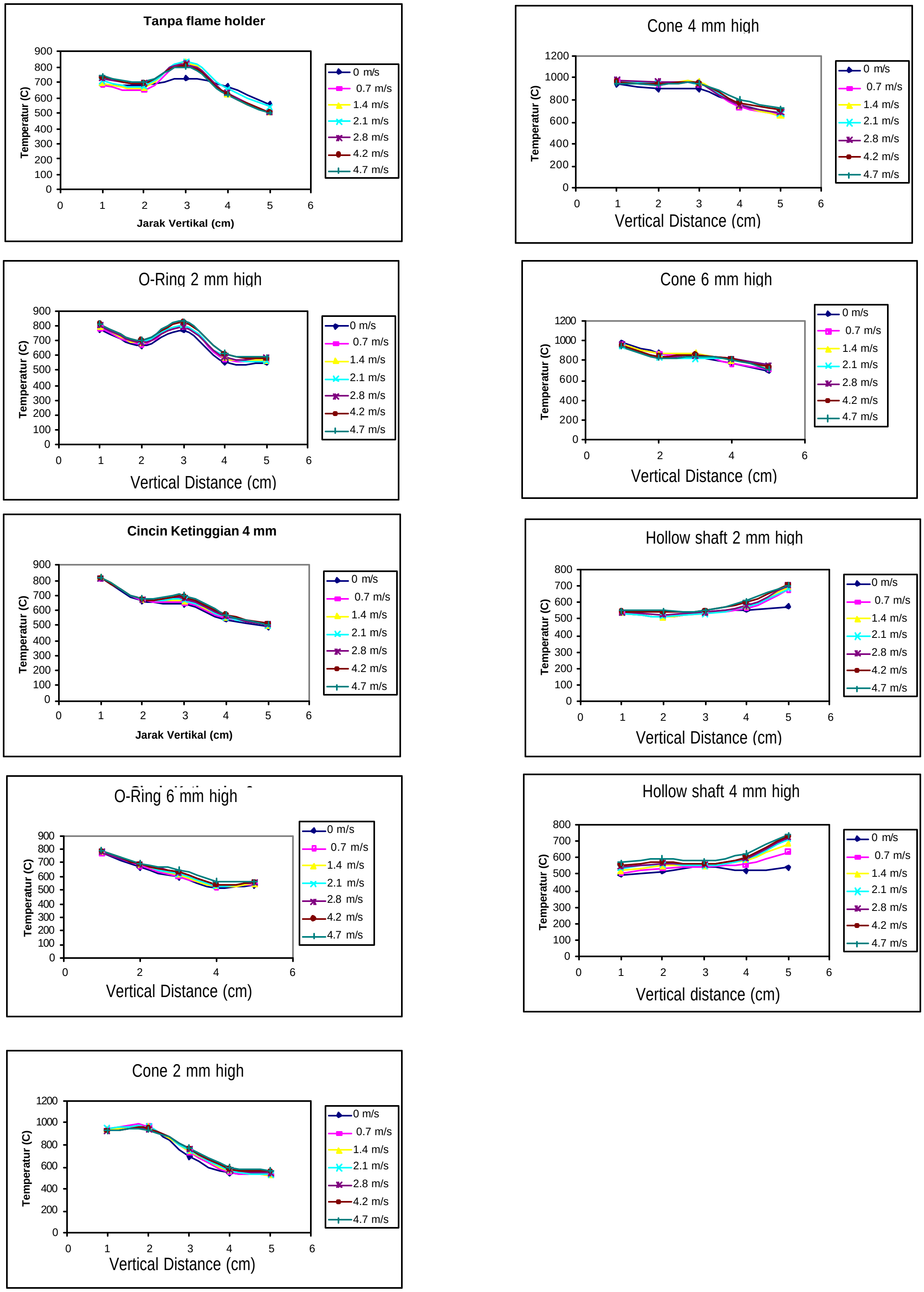


Fig. 6: Flame holder Vertical distance vs temperatur

Fig. 7. Flame Visualization

- This stability diagram is shown as a graph which is illustrating the air and fuel speed variation until a specific speed that the flame start to leave the burner port. These diagrams are showing the result of placing the flame holders variations between 2 cm, 4 cm, 6 cm, as shown on the graphs below:
- A graph that showing the relation between the flame holder position from the burner top end versus the flame temperature. The observation points were the distance between the flame holder and the top burner tip, from 1 - 5 cm.
- The flame flow pattern structure data was taken from a schlieren apparatus. The flame flow structure was taken from two conditions. First was the condition without the fire flame and second was the data taken with a burned gas condition.

DISCUSSIONS

In general, it could be seen that there was a significant flame stability zone shift. The o-ring flame holder type could increase the flame stability zone shift. On the o-ring model, the flame holder placement does not much alter the stability zone shift. But on the cone flame holder, there is an increase of the stability zone.

The hollow shaft flame holder could significantly increase the flame stability zone. Until the air speed was reaching 80 m/sec, no lift off take place. There are two possibilities, which is not yet been observe from this shift phenomenon, which was either the too low fuel speed or the hollow shaft flame holder ability in holding the flame.

On the temperature graph, the air speed raise does not affect the temperature distribution on the vertical direction. The temperature distribution, were induced by the flame holder installed. The flame holder shape strongly influence the graph shape. For graphs without a flame holder, the graph trend to be wavy with the top temperature at the third observing point, which is about 3 cm from the burner tip. After reaching that point the temperature tend to be decreasing. On the o-ring flame holder type, the temperature graph has a similar characteristic as of the combustion without a flame holder, especially for the o -ring at a 2 mm height from the burner tip.

On the cone shape, the highest flame temperature was reach at 700°C till 1000°C. Where as the flame temperature tend to lessen. The far the observe point the lessen the temperature. This is an indication that the air and fuel mixing process is getting lesser.

For the hollow shaft model, as seen on the flame stability diagram, it just generating the lowest combustion temperature compare with the other flame holder types If seen from the flame size, the flame produced has a large size, so that the heat produced will be radiated in a large flame zone. Consequently, the temperature value at these points was seen to be verry small compare to the other type of flame holders. At a point verry close to the flame holder, the temperature value was very small. It was because of the flame holder was functioned as a flame breaker, so that the flame in the burner area has a large size and the the flame disapear.

With an abillity as a verry good flow disturbance, the hollow shaft flame holder was able to steer the flow until far above the burner port. So, it can be concluded that the farther from the port the higher the flame temperature.

At an unburned gas condition, the visualization was verry clear. Ussually, the larger the air flow value the more turbulent the flow structure. At a stable condition, the bigger the air flow the larger the flame size take place. But, not on a lift off condition.

The flame size was constant, but the flow structure was more turbulent. On the difference flame holder shape, it was seen that there was just a verry small difference on the flow pattern structure. While on the cone type, there was a little turbulence. On the holow shaft flame holder, from the flow structure a stronger turbulence occure. On this flame holder type, the lift off visualization condition could not be recognized, because on this condition, lift off was never happen. Neverthelles, if the lift off phenomenon is reach, it was indicated that the flow pattern will be verry turbulence.

CONCLUSIONS

The flame stability limit, lift off and blow out, could be affected by the burner geometry in the combustion system installation. Consequently a flame holder should be put in to hold the flame as big as possible on a stable condition. The flame holder could disturb the air and fuel flow. The fluid flow blockage by the flame holder will generate vortex and this vortex will end up with a turbulence condition. This turbulence condition will shift the critical stability limit and will produce a perfect combustion.

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