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The Effect of Wire Mesh on Premix Combustion with Butane Fuel in Bunsen Burners

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ABSTRACT

Combustion is an important process in a variety of industrial, laboratory and household applications, and the use of devices that control the characteristics of the fire is essential. Bunsen burner is one of the common laboratory equipment used to produce flames in experiments and heating processes. Wire mesh is placed above the Bunsen burner to control air flow and has a crucial role in premix combustion by affecting efficiency, stability and heat distribution. In this study, an experimental investigation will be carried out on Bunsen burners using wire mesh 30, 40, and 50. Furthermore, parameters such as flame stability, flame height, and combustion speed will be measured. The results of this study indicate that the looser the wire mesh density, the burning speed tends to decrease. When using wire mesh 30, the value of the combustion velocity reaches 3.09 cm/s. Meanwhile, when using wire mesh 50, the value of the combustion velocity increased to 3.24 cm/s. This indicates that the wire mesh is getting tighter, air and fuel flow can move faster, thus increasing the combustion velocity. In addition, the density of wire mesh also affects the high flame produced. By using wire mesh 30, the flame height reached 29.69 mm, while using wire mesh 50, the flame height reached 21.56 mm. This shows that the higher the wire mesh density, the flame tends to be more stable and has a smaller height..

Key words : Bunsen burner, Wire mesh, combustion velocity, flame height.

1. INTRODUCTION

Combustion is an important process in a variety of industrial, laboratory and domestic applications. In an effort to improve the efficiency and safety of combustion, the use of tools that can control the characteristics of the fire is very important. Bunsen burner is the first burner that can produce premixed flame[1]. In this case the research device was made on a laboratory scale and in the premixed combustion process on a cylinder type bunsen burner [2].

Bunsen burners are used to produce flames that are used in various experiments and heating processes[3]. The fuel that is often used in Bunsen burners for premixed combustion is butane, which is a flammable gas and has a high potential to produce the heat needed for various purposes [4]. However, good control of the flame characteristics of the Bunsen burner is essential to ensure efficient, stable and safe combustion.

One of the elements that can affect the fire characteristics of a Bunsen burner is wire mesh or woven wire. Wire mesh is placed at the top of the Bunsen burner to control air flow. This wire mesh has a crucial role in premix combustion, which is a mixture of fuel (butane) and air before burning. The geometric parameters of metal wire mesh play a very important role in determining the fire resistance performance during fire evolution[5]. A single layer of wire mesh significantly increases the time tulip flame formation and makes the inversion rate of the fire front weak due to its effect on advancing and weakening the interaction of the fire front and pressure waves[6]. The use of wire mesh on Bunsen burner aims to increase combustion efficiency, flame stability, heat distribution evenly, as well as to provide additional protection to the user.

Previous research on the use of wire mesh has been carried out in various contexts[7][8][9][10]. One of the previous studies focused on the effect of wire mesh on premix combustion. In this study, wire mesh is used to control air and fuel flow to achieve a mixture that is close to the stoichiometry before combustion. The results found that the wire mesh significantly increased the wrinkling of the reverse flame front in the case of lean fuel combustion (Φ= 0.42), but weakened the rate of flame reverse for Φ=1.0, 1.59, and 2.38[5]. These conditions indicate that the use of wire mesh can increase combustion efficiency and produce a more stable flame. In addition, it is seen that the wire insertion method can effectively improve and also improves the distribution of temperature and its level along the walls and axis of the microcombustor[11].

Several previous studies have been conducted to evaluate the effect of wire mesh on the flame characteristics[12][13]. However, research on the effect of wire mesh on premix combustion with butane fuel is still limited. Therefore, this study aims to explain in more detail the effect of using wire mesh on premix combustion with butane fuel in Bunsen burners.

In this study, we will conduct an experimental investigation of Bunsen burners with and without the use of wire mesh. We will measure and analyze important parameters, such as flame stability, flame temperature, temperature distribution, combustion efficiency and gas emissions. It is hoped that this research can provide a better understanding of the role of wire mesh in premix combustion with butane fuel in Bunsen burners.

2. RESEARCH METHODS

This research was carried out experimentally regarding the characteristics of combustion which was carried out directly on the object under study to obtain causal data. The combustion method used during the test is premixed combustion. Premixed combustion occurs when fuel and air are mixed in the mixing chamber prior to the combustion process. A Bunsen burner is used to observe the flame shape. This burner has a burner tube with a length of 7.5 cm and a diameter of 1.02 cm. To obtain an even fire, wire mesh with sizes 30, 40 and 50 is used which is installed in the middle of the Bunsen burner. The research process schematically shows the use of the equipment as shown in Figure 1.

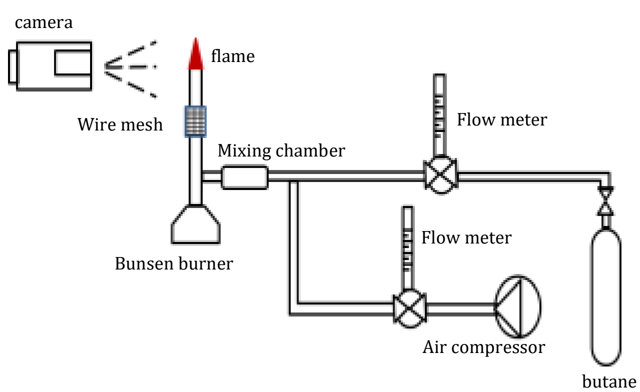

Figure 1: Laminar and flame combustion speed test equipment

Flame testing begins with passing butane gas into a Bunsen burner. The flow rate of the gas material is measured using a gas flow meter to ensure proper flow. Furthermore, fuel and air will meet in the mixing chamber. Inside the mixing chamber, air and fuel will mix and go to the Bunsen burner. Wire mesh is installed 30 mm from the mouth of the Bunsen burner. After the air and fuel mixtures pass through the wire mesh, they will flow into the mouth of the Bunsen burner. After that, using a manual lighter, the fire was lit. To analyze the behavior of the flames, a high speed camera was used with a high shooting speed of 180 fps.

The flame test was carried out using a wire mesh, and was repeated several times. The fuel flow is adjusted according to the ambient temperature. At the start of the test, the fuel flow was set at 1.667 cm^3/s. After the lighter is turned on, visualization of the flame is taken using a digital camera.
The test results are used to understand the effect of the equivalent ratio on laminar combustion and flame height. Before getting the value of the laminar combustion rate, calculations can be made using Equation[3] [14][15].

$$AFR = \frac{m_{air}}{m_{fuel}} \quad \text{...(1)}$$

AFR = air fuel ratio
m_{air} = air flow rate (kg/s)
m_{fuel} = mass flow rate of fuel (kg/s)

$$V = \frac{Q\,udara + Q\,fuel}{A} \quad \text{...(2)}$$

Information :
V : reactant rate
Q_{udara} : Air Debit (ml/s)
Q_{fuel} : fuel discharge (ml/s)
A : cross-sectional area (cm^2)

$$S_L = V.\ \mathrm{Sin}\ \alpha \quad \text{.. (3)}$$

Information
S_L : laminar burning rate (cm/s)
V : reactant rate (cm/s)
α : fire angle value (^{0})

After obtaining the fire visualization video, processing is carried out using the *JPG converter video* application to obtain flame image fragments. Every second of video is split into 180 images. Furthermore, these images are processed using the *ImagaJ* application to obtain information about the color and height of the flame. The results of this research are the angle of fire and the height of the fire. to measure can be observed in figure 2.

Figure 2: (a). Measurement of the height of the fire, (b). measurement of the angle of fire α

3. RESULTS AND DISCUSSION

The results of research on premixed combustion with variations in equivalent ratios and the use of wire mesh produce three main parts in the test. These sections include drawings, laminar burn rates, and flame height.

.**Analysis Flame**

The visualization results of the flame using butane gas fuel with wire mesh 30, 40 and 50 can be seen in Figures 3, 4 and 5 respectively.

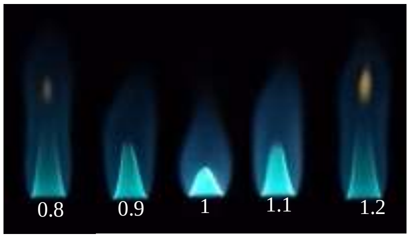

Figure 3: Visualization of fire with wire mesh 30

Figure 3 shows that the fire can continue to burn stably at a fuel discharge of 1.667 cm^3/s. The shape and height of the flame is affected by the mixture of fuel and air. The greater the air speed, the smaller the shape of the fire and can cause a blow-up phenomenon which results in extinguishing the fire.

At an equivalent ratio =1.2, the shape of the flame is divided into two colors, namely blue and red. The flame is conical and forms two layers. The thick blue inner layer is caused by premixed combustion, while the outer thin blue flame is the result of diffusion combustion. The closer to combustion with an equivalent ratio value of 1, the flame produces a brighter light because the combustion approaches stoichiometry. In addition, it is seen that the lower the equivalent ratio, the shorter the flame height.

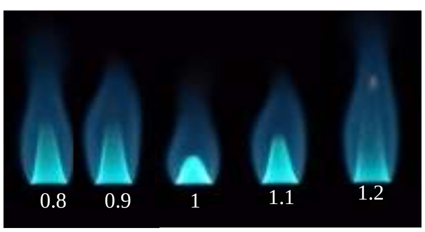

Figure 4: Visualization of fire with wire mesh 40

The use of wire mesh 40 in Figure 4. shows the difference in the color of the flames. Compared to a wire mesh of size 40, it can be seen that the amount of red in the fire is less. This shows that the use of wire mesh can limit the flow of air and fuel, so that the fuel mixture approaches stoichiometry. The closer to the stoichiometry, the thicker the blue layer of the flame becomes, indicating a more complete and efficient combustion process.

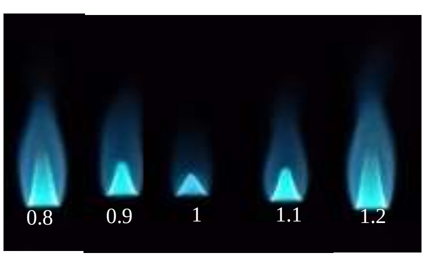

Figure 5: Visualization of fire with wire mesh 50

The denser the wire mesh 50, the mixture of butane gas and air can approach the stoichiometry, as shown in Figure 5. At an equivalent ratio of 1, the wire mesh can restrain the rate of fuel and air, so that after passing through the wire mesh, air and fuel mixed with approaching stoichiometric conditions. The use of wire mesh 50 produces a stable and controlled fire.

The formation of two angles of fire in this experiment is caused by changes in the composition of air and fuel. By maintaining a steady butane gas flow and changing the air flow rate, premixed laminar combustion occurs. The size of the angle of fire affects the speed of combustion, because the angle of the cone of fire is directly proportional to the speed of combustion. Thus, by adjusting the angle of fire, you can control the speed of combustion and optimize the combustion process.

The use of wire mesh in this combustion experiment has an important role in adjusting the ratio of air and fuel. The wire mesh provides resistance to the flow of air and fuel, thus creating a mixture that is close to stoichiometry. In effect, the resulting flame has a thicker blue color. This shows that the combustion is more complete and more efficient in achieving stoichiometric conditions.

3.1 High flame

The results of premix combustion using butane gas fuel can produce a significant flame height, as shown in Figure 6.

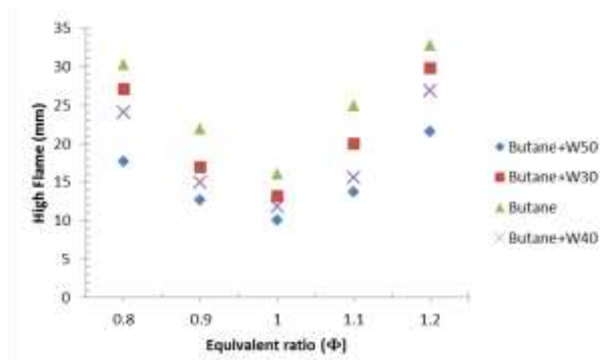

Figure 6: Graph of butane flame height to equivalent ratio

In Figure 6. it can be seen that there was an increase in flame height for various variations of wire mesh 30, 40, and 50. The results showed that the Bunsen burner with wire mesh 30, the highest flame height reached 29.69 mm, while the height the lowest flame reaches 13.13 mm. At the equivalent ratio $\phi = 1$, the flame height with wire mesh 40 reached 11.85 mm and the highest flame height reached 26.85 mm. In wire mesh 50, the highest flame height reached 21.56 mm, while the lowest flame height reached 10.06 mm.

The results showed that the use of wire mesh as a barrier to the flow rate of fuel and air can create a mixture that is close to stoichiometric conditions, and this can be seen in Figure 4 with a stable flame height. The thinner the wire mesh size, the flame height tends to increase, while the denser the wire mesh size, the flame height tends to decrease. The results of research on premix combustion using wire mesh provide a better understanding of the effect of wire mesh in achieving a more efficient and stable combustion. The use of wire mesh in a premix combustion system can increase stability, efficiency, and reduce the resulting emissions. By continuing to develop and improve wire mesh designs, it is hoped that premix combustion technology using wire mesh can be widely implemented to face energy and environmental challenges in the future.

From these results, it can be concluded that variations in the size of the wire mesh affect the height of the resulting flame. The larger the size of the wire mesh, generally the flame height will tend to increase. However, it should be noted that there is variation in flame height between the different sizes of wire mesh used. In addition, the equivalent ratio can also affect the height of the flame, where at the equivalent ratio ϕ = 1, there is a difference in the height of the flame between the use of wire mesh of different sizes.

3.2 Laminar burning velocity

Testing the laminar burning speed with variations in the equivalent ratio resulted in a significant difference in burning speed. The results of the combustion speed test (S_L) can be seen in Figure 7.

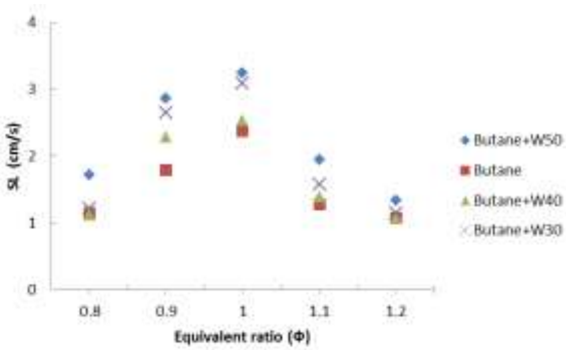

Figure 7: Graph of the relationship between combustion velocity and equivalent ratio

From Figure 6, it can be seen that the combustion speed is affected by the use of wire mesh. This is because the wire mesh is able to make the fuel-air mixture more quickly approach stoichiometric conditions. The burning speed has a proportional relationship with the size of the angle, as shown in Figure 8 with an equivalent ratio of ϕ = 1 and using wire mesh sizes 30, 40 and 50.

In a Bunsen burner with a wire mesh size of 30, the combustion speed close to the stoichiometric condition ϕ = 1 is 3.09 cm/s, while the lowest speed value is 1.14 cm/s caused by a decrease in air velocity. When the air speed is increased, the value of the combustion speed of wire mesh 40 reaches 2.54 cm/s. However, if the airflow velocity is increased further, a blow up will occur in the flame causing it to extinguish the flame. In wire mesh size 40, the angle of fire is slightly larger and affects the combustion speed at an equivalent ratio of ϕ = 1.1 of 1.39 cm/s, while the highest combustion speed reaches 2.54 cm/s. In a Bunsen burner with a wire mesh size of 50, the combustion speed is close to the stoichiometric condition ϕ = 0.9 with a value of 2.89 cm/s, while the highest combustion speed reaches 3.24 cm/s, indicating that a wire mesh of size 30 is capable of forming a stoichiometric flame faster. with a stable combustion rate.

It can be concluded that the denser the wire mesh density, the burning speed tends to decrease. In addition, the higher the value of the equivalent ratio, the burning speed will also decrease. This is caused by the availability of less air in combustion under rich conditions, so that the angle of fire tends to be smaller and the velocity of the reactants becomes low.

4. CONCLUSION

Based on the results of observations and data analysis in this study, several conclusions can be drawn as follows:

1. The density of the wire mesh serves as a barrier to the flow rate of air and fuel to obtain a stoichiometric mixture after passing through it. The wire mesh plays a role in regulating the speed and distribution of fuel and air to create optimal combustion.
2. The looser the wire mesh density, the burning speed tends to increase. For example, using wire mesh 50, a burning speed value of 3.24 cm/s was achieved. Whereas in wire mesh 30 , the value of the combustion speed reached 3.09 cm/s. This shows that the looser the wire mesh, the air and fuel flow can move more freely, thus increasing the combustion speed.
3. In addition, the density of the wire mesh also affects the height of the flame produced. By using a 30 mm wire mesh, the flame height reached 29.69 mm, while the 50 wire mesh, the flame height reached 21.56 mm. This shows that the higher the wire mesh density, the flame tends to be more stable and has a greater height.

The density of the wire mesh plays an important role in regulating the flow rate of air and fuel, so that after passing through it, the air and fuel mixture can approach stoichiometry and create a stable flame.conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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