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Laminar Burning Velocity of *Calophyllum inophyllum* Methyl Ester on Perforated Burner

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Abstract. Laminar burning velocity is the volume of unburned gas per unit time distributed by the gas consumed. The laminar burning velocity has an important role because it contains basic information about fuel reactivity, diffusivity, and exotherms in the combustion process. In addition, laminar burning velocity is important to identify for calculation in fuel storage explosion protection. This study explains the characteristics of the laminar burning velocity of *Calophyllum inophyllum* methyl ester using perforated burner method. The fuel used are 0%, 20%, 40%, 60%, 80%, and 100% (B0, B20, B40, B60, B80 and B100) blending fuel of *Calophyllum inophyllum* methyl ester and petroleum diesel. Fuel rate is 60 ml/hour (1 ml/minute) using a syringe pump to control which is then evaporated at 180 °C. The observations of laminar burning velocity with variations of equivalent ratio Ø 0.6 to Ø 1.4 using B0 to B100 fuel showed that the value of laminar burning velocity rate continued to decrease along with the increase in the *Calophyllum inophyllum* methyl ester blending ratio. Blending fuel B20, flame can be observed with variations of Ø 0.6 to Ø 1.4, while in materials on fuel B40, B60, B80, and B100 the flame cannot burn up at equivalent ratio Ø 0.6. Flammability limits of blending B40, B60, B80, and B100 fuels which are only able to burn up at an equivalent ratio of more than 0.6, this phenomenon shows that the maximum ratio of *Calophyllum inophyllum* methyl ester blending has characteristics approach diesel is the B20 blending ratio. Laminar burning velocity for each equivalent ratio on each fuel continues to decline, even at Ø = 0.6 only B0 and B20 fuels are burned up and observable, while other fuels do not ignite and achieve flammability limits. The increasing biodiesel blend shows the laminar burning velocity in each of the equivalent ratio continues to decline, this is caused by several factors such as density, viscosity, auto ignition, and increasing C-O fuel ratio.

INTRODUCTION

Modern society is now too dependent on technological assistance to support their daily needs, the dominant energy source used by technology today is fossil energy such as coal, petroleum, and natural gas with increasingly depleting supplies [1]. Dependable fossil energy source during this time will run out and take a long time for reuse, therefore the transfer of renewable energy technologies must be realized. Several efforts have been made to reduce the use of fossil energy sources, which is by using renewable energy sources such as wind, ocean waves, geothermal energy, solar, and biofuels. Biofuel, like biodiesel, is the most easily distributed source of renewable energy because it can be utilized in various fields such as industry, power generation, transportation, and household use.

Biodiesel is a renewed fuel that replaces reserves and fossil fuels by changing the content of free fatty acids (FFA) in organic feedstock into methyl esters of fatty acids (FAME) [2]. Biodiesel has long been known as the renewable

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fuel with a variety of raw materials for making such as *Cocos nucifera*, *Elais guineensis*, *Jatropha curcas*, and various other organic feedstock. Research on other organic feedstock submitted as raw material for making biodiesel is still being done, one of propose to use the feedstock is *Calophyllum inophyllum* [3]. From a variety of other feedstock for biodiesel *Calophyllum inophyllum* has many advantages compared to other raw materials, such as not disturbing the food sector (non-edible food), the tree can be productive for up to 50 years, has a high oil yield of around 40-73 %, and the characteristics of biodiesel qualify ASTM D6751 and EN 14214 standards [4]. Research on biodiesel as fuel continues to be developed to improve the efficiency of combustion.

Combustion is a chain chemical reaction that quickly at high temperatures and is followed by the transfer of some heat. The combustion process has a function to convert the chemical energy of fuel into heat energy [5]. The main requirements about a combustion process must contain three elements, namely fuel, oxidizing, and heat. Three unimportant combustion processes are called combustion triangles, one of which is not eliminated, the combustion process will stop. Flame in the combustion process can we observe to determine the quality of combustion, such as the color of the flame, the angle of flame, high flame, also the rapid propagation [6]. Diffusion combustion is a combustion process that occurs in burning fuel and oxidizer during the process. Premix combustion is the opposite of diffusion combustion, combustion occurs premix fuel and oxidizer has been mixed in advance with the mechanics by choosing certain. Diffusion combustion, as well as premix, require heat-activated energy for the process to be carried out as expected shown in Figure 1 [7].

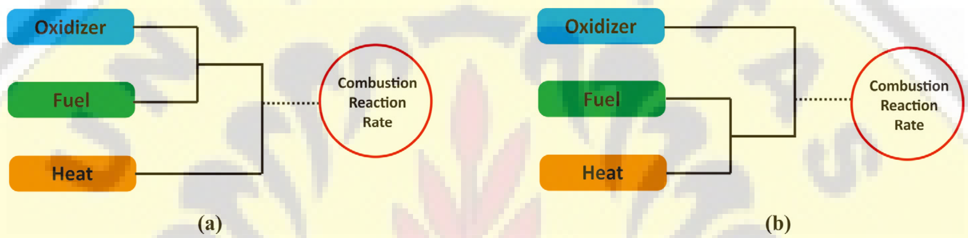

FIGURE 1. Schematic of (a) Premixed Combustion and (b) Diffusion Combustion

The characteristics of biodiesel must qualify predetermined standards that can be used on a general scale, standards that are often used are the viscosity, density, flashpoints, cetane value indexes, calorific values, lubrication capabilities, lubrication content, sediment content, and color. As a fuel that contains substitutes, biodiesel is often blended with fossil fuels [3]. Accurate information about fuels characteristics is important for the purposes of determining engine design, combustion modeling, chemical use validation, and safety, other parameters that need to be considered in using fuel in this study are improvements to laminar burning velocity.

Laminar burning velocity is determined as the volume of unburned gas per unit time divided by the gas consumed [7]. Laminar burning velocity has an important role in the combustion process because it contains basic information about the reactivity of fuel, diffusivity, and exothermic in the combustion process. In addition, the laminar burning velocity is very important for calculations in fuel storage explosion protection [8]. The equivalent ratio (Ø) is an important parameter to control the reaction and also the observation of the flame because it affects the rate of the oxidizing reaction to the fuel during the repair process. Research on the laminar burning velocity is being developed to determine the characteristics of each fuel, several methods have been used such as heat flux burners, flat burners, bunsen burners, slot burners, tube propagating, and perforated burners [9]. There are several methods to determine the value of the laminar burning velocity but in general, the bunsen burner method is more often used because it processes data more simply by visualizing the flame. In some monitoring using a bunsen burner, a perforated plate is added to improve the accuracy of visual observation of the flame to make it more stable and easier to observe [10]. Perforated burners are a method of developing bunsen burners to carry out visual observations of the combustion process. Visual flame observations intended to determine the quality of combustion that occurs. Observation using perforated burners is easier to observe because the flame conditions become more stable.

METHODOLOGY

Research on the laminar burning velocity of the ***Calophyllum inophyllum*** methyl ester using the perforated burner method. The fuel used is a mixture of diesel fuel with *Calophyllum inophyllum* methyl ester. The biodiesel blending ratio used is B0, B20, B40, B60, B80, and B100. The fuel discharge (1 ml/min) is installed using a syringe pump which is then evaporated with a 180 ˚C heater and ignited until the flame is lit shown in Figure 2.

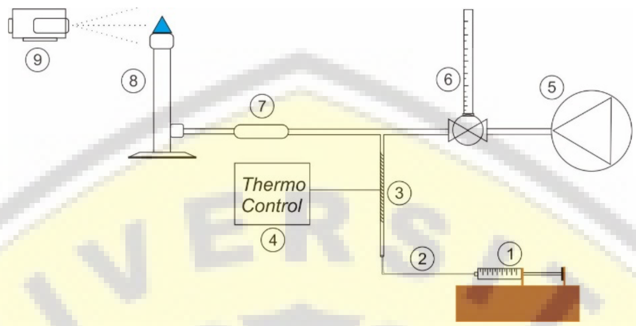

FIGURE 2. Combustion Research Scheme

1. Syringe pump
2. Silicone hose
3. Heater
4. Thermo Control
5. Compressor
6. Flowmeter
7. Mixing chamber
8. Perforated Burner
9. Camera

AFR (Air Fuel Ratio) is controlled using a flowmeter with an air source in the form of a compressor. The air filter comes out first to filter out water vapor / other unwanted substances. The equivalent ratio variations used are 0.6, 0.8, 1, 1.2, and 1.4. Fire observation using a Canon Kiss X7 5184 x 3456-pixel camera, shutter speed 1/50, ISO 3200, using a 55 mm macro lens, manual settings with an observation distance of 50 cm. The alpha angle (α) on the flame can be used using Image-J freeware as agreed in Figure 3.

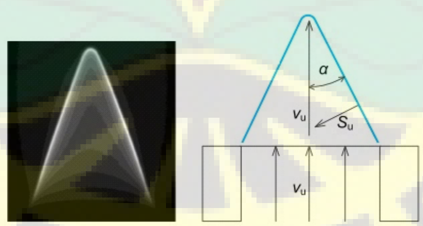

FIGURE 3. Determine Alpha Angle

To processing data, the observed flame is recorded using the camera and then converted into an image. ImageJ freeware is used to measure the α (alpha) angle. The laminar burning velocity can be known using Eq. (1) and (2)

$$SL = v \sin \alpha \tag{1}$$

$$v = \frac{Q\,fuel + Q\,react}{A} \tag{2}$$

Laminar burning velocity values obtained from each variation equivalent ratio and mixture ratio are calculated based on the assessment of the flame angle and reactant speed.

RESULT AND DISCUSSION

Calophyllum inophyllum is blended with diesel fuel and discovers the combustion characteristics of the laminar at various variations of the equivalent ratio using a perforated burner. The results of observing the combustion speed of the laminar with variations Ø = 0.6 to Ø = 1.4 using B0 to B100 fuels shown in Figure 4.

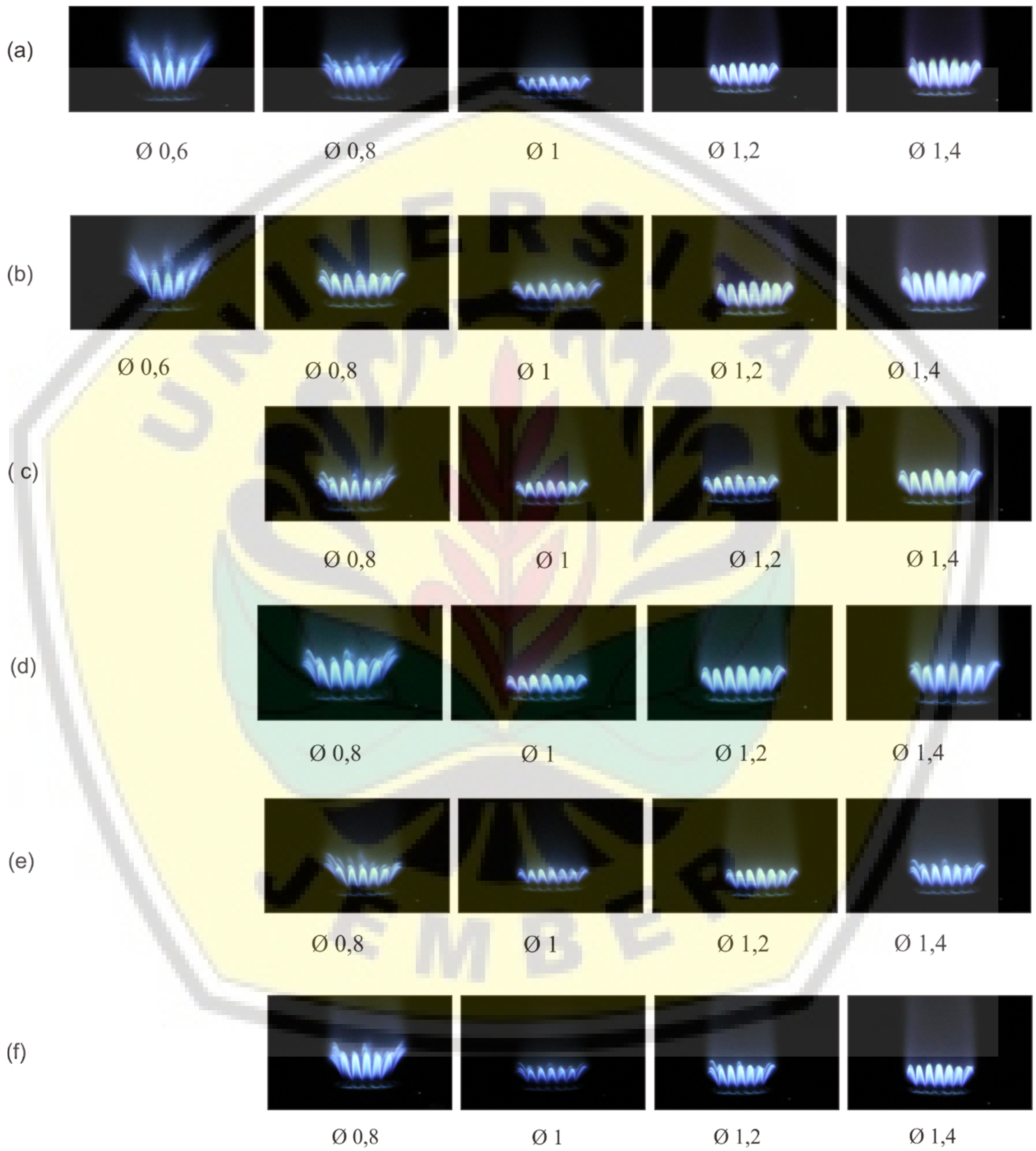

FIGURE 4. Combustion On Perforated Burner at various blend (scale 1:2) (a) B0 (b) B20 (c) B40 (d) B60 (e) B80 (f) B100

The laminar burning velocity value continues to increase with increasing ratio of *Calophyllum inophyllum* methyl ester mixture. On the B20 blend fuel the flame can be seen with variations Ø = 0.6 to Ø = 1.4, while on blend fuel B40, B60, B80, and B100 the flame can not be observed at Ø = 0.6. This shows that the B40, B60, B80, and B100 fuel combustion limits are only capable of being activated at an equivalent ratio of more than Ø = 0.6. This phenomenon shows the maximum mixing ratio of *Calophyllum inophyllum* methyl ester which has the characteristic of changing diesel fuel is the mixing ratio of B20. The laminar burning velocity of each fuel varies in an equivalent ratio of 0.6 to 1.4. The velocity value at the blending ratio of each renewal fuel shown in Figure 5.

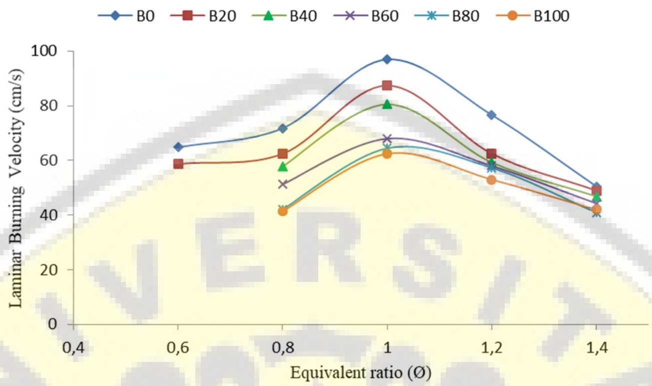

FIGURE 5 Laminar Burning Velocity on B0, B20, B40, B60, B80, B100

The laminar burning velocity of each fuel varies in an equivalent ratio of 0.6 to 1.4. The velocity value at the equivalent ratio of each renewal fuel in Figure 6.

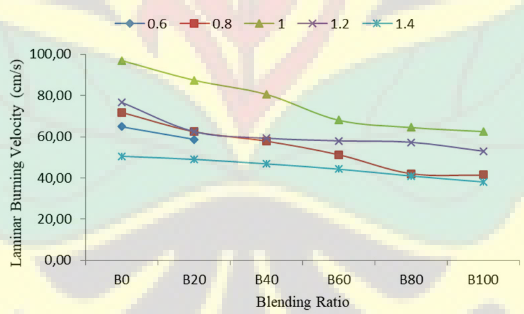

FIGURE 6. Laminar Burning Velocity at equivalent ratio 0.6; 0.8; 1; 1.2; 1.4

Based on these data, the laminar burning velocity value of each equivalent ratio in each fuel continues to increase, even at Ø = 0.6 only B0 and B20 fuels are activated and can be used, while the available fuel can not reach the flammability limit. The higher efficiency of *Calophyllum inophyllum* methyl ester shows the laminar burning velocity at each equivalent ratio continues to increase, this is caused by several factors such as density, viscosity, automatic ignition, and increasing fuel C-O ratio.

CONCLUSION

After the research and data processing has been completed, the highest value of the laminar burning velocity of each fuel in each burner in accordance is the equivalent ratio Ø = 1, and continues to increase approaching the equivalent ratio of Ø = 1. Each equivalent the ratio is B20 fuel and continues to increase along with the increasing ratio of *Calophyllum inophyllum* biodiesel mixture.

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