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Flame Characteristics of Diffusion of Calophyllum inophyllum Methyl Ester on Mini Glass Tube

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ABSTRACT

Combustion is a chain chemical reaction that is influenced by three factors, namely fuel, oxidizer, and heat. This study analyzes the effect variations of fuel flow rates (1 ml/h, 2 ml/h, and 3 ml/h) on the laminar burning velocity, flame height and flame stability as seen from the number of explosions. This study uses Calophyllum inophyllum methyl ester fuel. In the diffusion combustion process, the fuel mixes with the oxidizer naturally. In this study, it is known that the flow rate of 1 ml/h produces the highest average laminar burning velocity value of 0.0023 m/s and the lowest laminar burning velocity value is 0.0020 m/s at the flow rate of 3 ml/h. Whereas for the height of the flame has the highest average value at the flow rate of 3 ml/h which is 27.98 mm and the lowest average high flame value at the fuel flow rate of 1 ml/h is 2.9 mm.

Keywords:
Calophyllum inophyllum, Glass Tube, Diffusion Flame Characteristics

1. Introduction

The rapid development of the human population is also accompanied by increasing energy consumption, energy sources that are still widely used are fossil energy, especially petroleum fuels [1]. Fossil fuels are used in almost all energy supply needs such as transportation, industry, power generation, and households [2]. Alternative and renewable energy is developed to substitute fossil energy and overcome the excessive used of fossil fuels, one of which is biodiesel [3].

Calophyllum inophyllum is a potential source of biodiesel feedstock, because of its high oil content and its plants can grow well in the tropics [4]. Crude oil obtained can not be directly used as fuel because of its high viscosity and can inhibit the combustion injection process, therefore crude oil needs to be processed again into biodiesel to reduce its viscosity [5-7], there are several biodiesel processing methods such as thermal cracking, pyrolysis, emulsification, and transesterification [8]. Commonly transesterification is more often used because of the simple processing and produce high biodiesel yields. The transesterification process converts triglycerides added with alcohol into esters and glycerol, this ester compound is called biodiesel [9-11] shown on Figure 1. This work producing

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biodiesel from Calophyllum inophyllum as feedstock using ultrasound-assisted transesterification methode (T = 25 °C; t = 40 minutes; ratio solvent to oil = 6:1 m/m; ratio catalyst to oil = 1 % w/w). Biodiesel is a promising alternative energy source because of the sustainability of feedstock and classified competitive fuel [12-13].

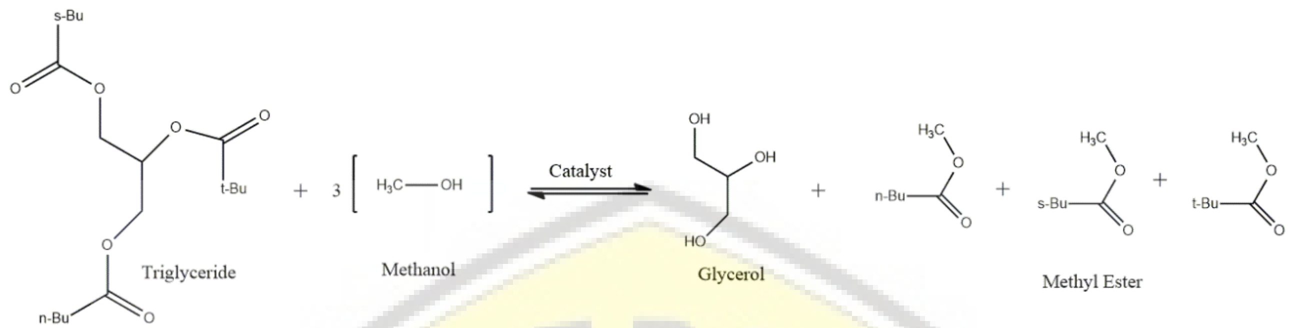

Fig. 1. Scheme reaction of transesterification process

Fuel is important component in the combustion process because the conditions for combustion must consist of three main components including fuel, oxidizer, and heat. Combustion is a chain chemical reaction that takes place rapidly at high temperatures and is accompanied by the displacement of heat [14]. The combustion process has a function to convert the chemical energy of the fuel into heat energy which can then be used directly or converted into other energy such as motion or electricity.

The combustion reaction requires the activation energy in the form of heat for the continuation of the reaction, if the activation energy is greater than the energy produced by the combustion, then the combustion efficiency certainly small and ineffective, therefore further research is needed regarding the combustion characteristics of each fuel property. Biodiesel as a liquid fuel needs to vaporized to continued in the combustion process by heating the fuel and giving oxidizers [15]. Diffusion combustion is a combustion process which the fuel and air as oxidizing agents do not mix mechanically but are allowed to mix themselves naturally through the diffusion process follow the combustion reaction shown in Figure 2.

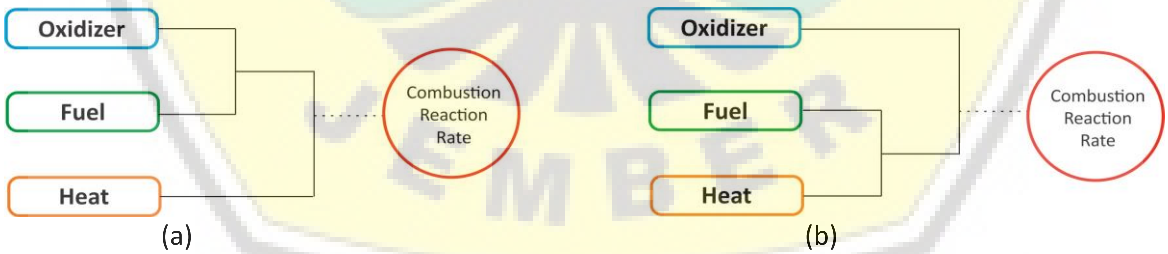

Fig. 2. Schematic of (a) Premixed Combustion and (b) Diffusion Combustion

Research by Chen [15] examined the characteristics of ethanol diffusion combustion on a mini glass tube, the study concluded that the flow rate of the fuel affected the flame stability. Increased flow rate causes the fuel to flow into the mouth of the tube, the interface becomes unstable and an explosion occurs in the mouth of the tube. Research on Calophyllum inophyllum biodiesel is often carried out on 1-cylinder diesel engines, with observations on performance, emission testing, endurance, and fuel consumption, but research on the characteristics of diffusion combustion is rarely [16]. Therefore the researcher tried to research on the characteristics of the diffusion combustion of Calophyllum inophyllum on a mini glass tube.

2. Methodology

In this diffusion combustion characteristic research using Calophyllum inophyllum methyl ester with a flow rate variation of 1 ml/h, 2 ml/h, and 3 ml/h with range heating value is 300-400 ^{o}C to determine the flame height, flame stability, and the laminar burning velocity. The Calophyllum inophyllum methyl ester properties is shown in Table 1.

Table 1
Properties of Calophyllum inophyllum methyl ester

Characteristics	Result
Viscosity (cSt)	4,88
Density (g/ml)	0,843
Flash point (^{o}C)	135
Caloric value (cal/gram)	9448, 95

The equipment used in this study are glass tubes with an inner diameter of 1.5 mm and an outer diameter of 6.5 mm, syringe pump, clamp and stative pole, camera 30 fps, digital thermometer, silicon hose, copper tube, and heater as shown in Figure 3.

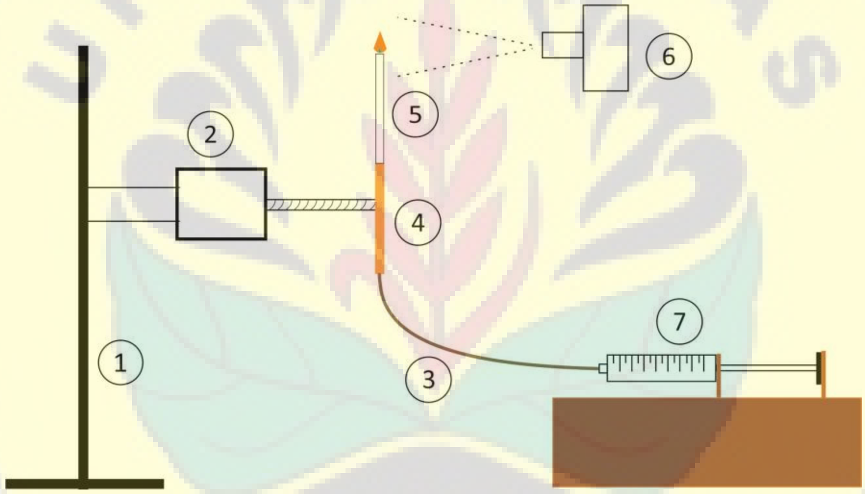

Fig. 3. Installation set-up

Properties

i. Stative pole
ii. Heater and thermometer
iii. Silicon Hose
iv. Copper tube
v. Glass tube
vi. Camera
vii. Syringe pump

To processing data, the observed flame is recorded using the camera and then converted into an image. ImageJ software is used to measure the flame height and measure the α (alpha) angle. The laminar burning velocity can be known using Eq. (1) and (2) [17].

$$SL = v \sin \alpha \quad (1)$$

$$v = \frac{Q}{A} \quad (2)$$

SL is laminar burning velocity and α is the flame angle shown in Figure 4, v is the fuel velocity that can be known by dividing the known fuel discharge with the glass tube surface area that flowed by fuel.

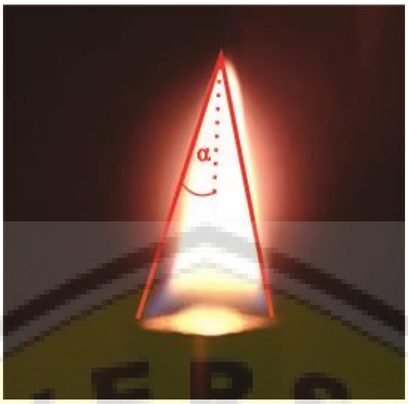

Fig. 4. Flame angle measurement

The laminar burning velocity is one of the important parameters to determine the quality of fuel in the combustion process. The laminar burning velocity is defined as the volume of unburned gas per unit time divided by the gas consumed.

3. Results

The basic phenomena that occur in this study are observed visually based on the data obtained from the recordings that continue converted into images as shown in Figure 5-7, visual observations using ImageJ software to determine the height of flame and alpha angle. The flow rate of the fuel is varied to 1 ml/h 2 ml/h and 3 ml/h, the inner diameter is 1 mm and the glass tube height is 70 mm, to get the fuel flow velocity using Eq. (2) and (3).

$$A = \pi . d . t \tag{3}$$

Using Eq. (2) and (3) it is known that the fuel flow velocity at 1 ml/h, 2 ml/h, and 3 ml/h discharges is 0.00455 m/s, 0.00909 m/s, and 0.013649 m/s.

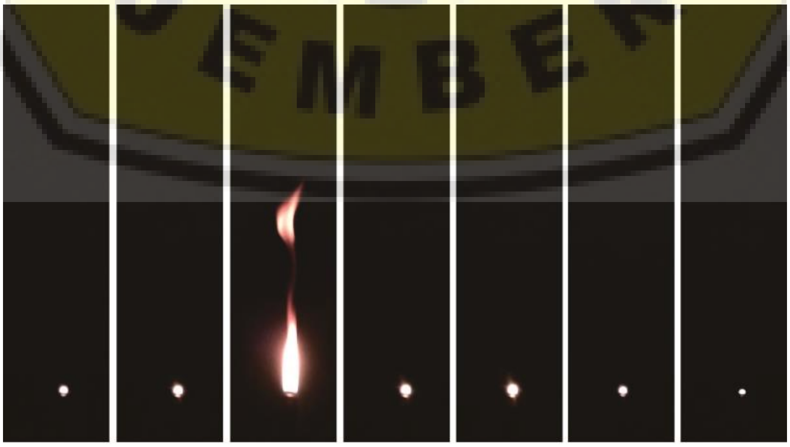

Fig. 5. Flame at flow rate 1 ml/h

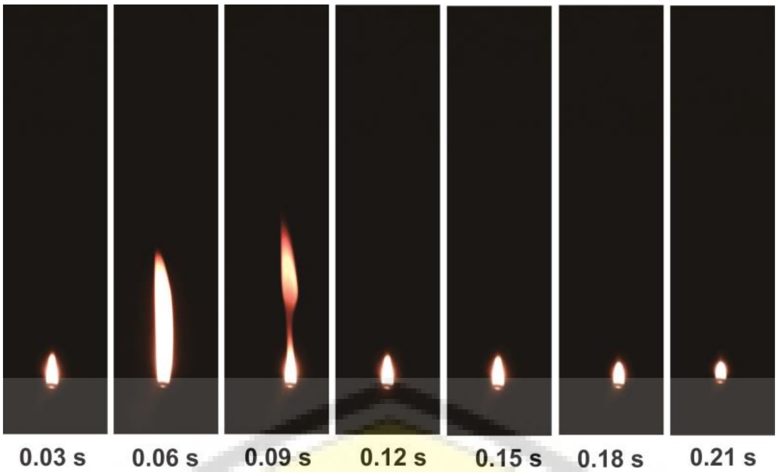

Fig. 6. Flame at flow rate 2 ml/h

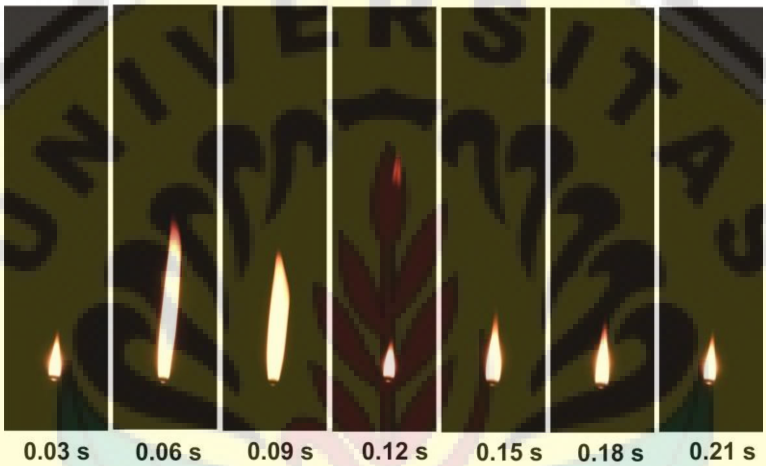

Fig. 7. Flame at flow rate 3 ml/h

3.1 Laminar Burning Velocity (SL)

The obtained flame angle value was further processed with the formulation in Eq. (1) that a graph of the value of diffusion laminar burning velocity was obtained with the variation of the flow shown in Figure 8.

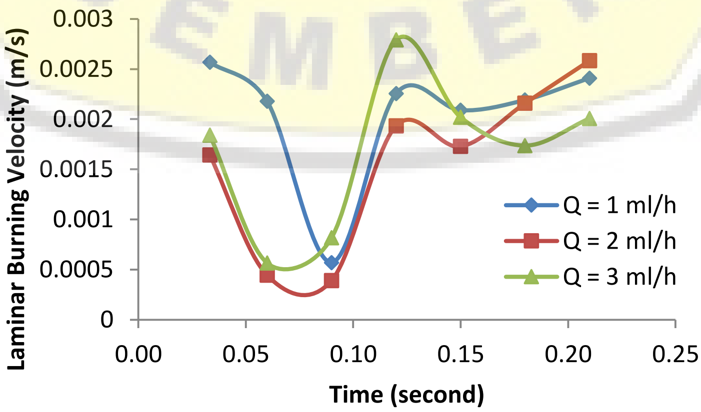

Fig. 8. Laminar burning velocity of diffusion flame

The value of the laminar burning velocity decreases when an explosion occurs in all variations of the discharge. The discharge variation 1 ml/h has the highest average value without the explosion are 0.0023 m/s followed by discharge variation of 2 ml/h and 3 ml/h which is 0.00208 m/s and 0.0020 m/s. The value of the laminar burning velocity decreases with the increase of discharge, this occurs because the fuel volume increases but not also followed by the volume of oxidizer at the same interface because in the combustion process the oxidizing diffusion mixes naturally.

3.2 Height of Flame

Different from the value of laminar burning velocity, the height of the flame diffusion increases when an explosion occurs and the height of the flame also increases with increasing fuel discharge is shown on Figure 9. The average height of fire at 1 ml/h, 2 ml/h, and 3 ml/h was 2.9 mm, 12.48 mm, and 27.98 mm, the average value calculated without explosion.

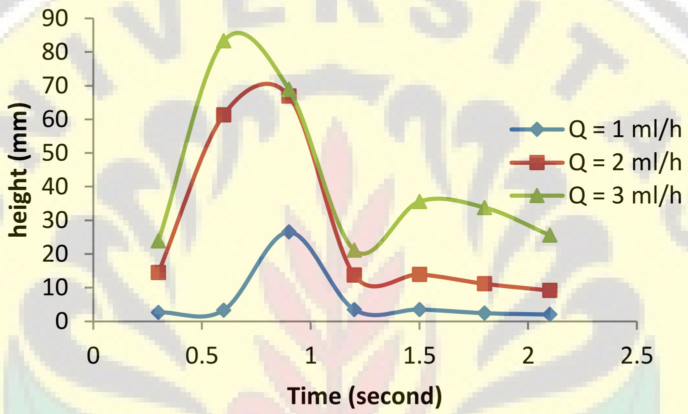

Fig. 9. Height of diffusion flame

The greater flow rate of fuel in diffusion combustion can increase height the flame, this occurs because the combustion speed is lower, so that the unburned fuel will evaporate upwards and just been oxidized by the oxidizer so that the combustion reaction occurs. In diffusion combustion there is an explosion in the flame which occurs due to the inconstant rate of fuel evaporation, it can be seen that the greater the fuel flow rate the number of explosions also increases as shown in Figure 10.

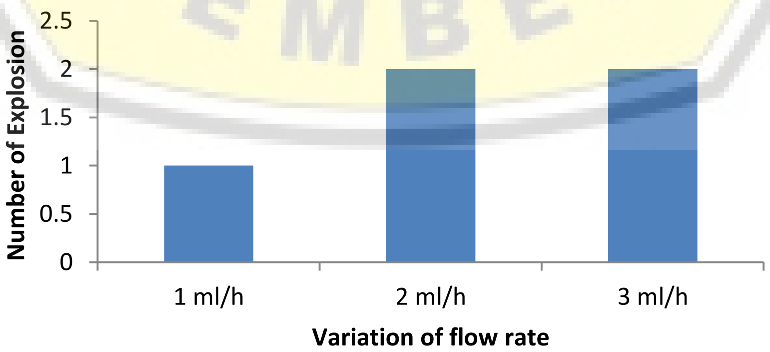

Fig. 10. Explosion of diffusion flame

4. Conclusions

The laminar burning velocity on diffusion combustion and high flame with variations in the flow rate of fuel has been observed, it can be concluded that the value of the laminar burning velocity using the mini glass tube burner method will continue to decrease along with the increase of the height of flame produced because the angle formed also decreases. The flame is getting higher because of the increase in fuel flow rate so that the surface area of combustion also increases. Increased fuel supply also requires excessive oxidizing to occur in the combustion process, so that the fuel vapor on the surface of the mini glass tube bunsen burner that has not been oxidized and burned will continue to flow upward until the fuel vapor is oxidized and burned, this is what makes the flame more high when the fuel flow rate increases.

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