Analysis of ignition delay and burning rate of dammar resin

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Abstract. This study aims to determine the ignition delay and the burning rate of dammar resin. The test is carried out by observing the process starting with the fall of the dammar resin above the furnace then starting to form until the combustion process ends. Observations were made using a Canon G15 digital camera that has the ability to record movies at speeds of 240 fps. The analysis was carried out by first changing the recording results into an image using the program free video to jpg converter v.5.0.43 build 605. The results were obtained in the form of the mass relation of dammar resin material (g) to the ignition delay (s) in the equation

\[ Y_I = -170.8X_w^2 + 8.258X_w + 1.631. \]

The mass relationship of dammar resin material (g) with the duration of combustion time (s) in the equation

\[ Y_{t\text{h}} = 87.64X_w + 1.373. \]

The mass relation of dammar resin material (g) to the burning rate (g/s) in the equations

\[ Y_{v_m} = -0.497X_w^2 + 0.099X_w + 0.004. \]

The relationship of the initial diameter of dammar resin (mm) on the flame distribution rate (mm²/s) in the equation

\[ Y_{vD} = -0.051X_D^2 + 0.306. \]

1. Introduction
Currently, the efforts continue to be made so that the world's energy needs can be met, including efforts to optimize the use of energy both existing energy such as water energy [1], solar energy [2-3] etc. Efforts to meet energy needs are also carried out by finding alternative and renewable energy [4-12]. The increasingly limited petroleum reserves and air pollution problems, so that it becomes an urgent need for the use of alternative fuels [4]. Therefore, joint efforts are needed to obtain alternative fuels that are equivalent and even superior and environmentally friendly [5].

Efforts to reduce exhaust emissions are also carried out by using alternative fuels from plant sources, including tobacco seed oil [6], tomato seed oil [7], vegetable oil [8] and soybean oil [9]. One of the plants that are also suitable as an alternative fuel is dammar resin (Dipterocarpaceae) because it contains hydrocarbons and other carbon compounds [10-11]. This content indicates that dammar resin has the potential to be developed as an alternative fuel. The feasibility of alternative fuels is determined by many factors, including the ignition delay and the burning rate [12]. As for research with alternative oil of jatropha oil [12] obtained results as shown in Figure 1.

This research was conducted to determine the flammability of dammar resin, i.e. the ignition delay and the burning rate of dammar resin.
2. Methodology

Testing of dammar resin combustion is done to determine the flame properties of dammar resin which is related to the function of dammar resin as an alternative renewable fuel.

The flame properties of the dammar resin observed were ignition time and ignition time. The equipment used is a furnace and a digital camera. The digital camera used is the Canon G15, this camera has the ability to record movies at speeds of 240 f/s. The experimental scheme can be seen in Figure 2. The samples observed were solid dammar resin. Before testing is done the selection of clean solid dammar resin.

![Figure 2. The experimental scheme of combusting low mass.](image)

The test is done by turning on the furnace for 5 minutes, after that the digital camera with 240 f/s is turned on, then dropping the dammar resin over the furnace, shortly after the dammar resin turns on, turn off the furnace fire, observe the dammar resin ignition until it goes out, after dammar resin turns off the digital camera. The test done with a variation of the weight of the dammar resin is 0.02; 0.04; 0.06; 0.08 and 0.10 g and each weight variation was tested 5 times.

The time of dammar resin falls into the furnace until the combustion process occurs was called the ignition delay. The burning rate is measured by the mass of the material divided by the time of combustion. The burning time is measured from the start of the burning of the dammar resin on top of the furnace until it goes out. The results of digital camera readings are in the form of a video with MOV format; for processing video data then converted into an image using a program free video to jpg converter v.5.0.43 build 605.

3. Results and discussion

In dammar resin combustion with a material mass variation of 0.02 to 1.0 grams, when the dammar resin is dropped on the furnace, the dammar resin is not directly burned. The time of the dammar resin falls into the furnace until the combustion process occurs is called the ignition delay. The relation of
the dammar resin mass (g) to the ignition delay (s) can be seen in figure 3. In the picture, the relationship that forms a curved line with the equation of the line is:

\[ Y_I = -170.8X^2 + 8.258X + 1.631 \]  

(1)

**Figure 3.** Effect of the dammar resin mass on the ignition delay (s) of dammar resin.

In Figure 3 shows that the larger the mass of dammar resin, the shorter the ignition delay, this is because the mass of the dammar resin, the large amount of gas formed from the heating results more and more so that a certain amount of gas is burned and forms a flame. The same tendency is also generated in the combustion of jatropha oil [12] as shown in Figure 1 (a) where the greater the diameter of the droplet (the greater the mass), the faster the ignition delay.

In dammar resin combustion, the ignition delay at 0.02 grams of material mass (equivalent to one drop of liquid fuel) is around 1.68 - 1.83 seconds (Figure 3), when compared with the results of jatropha oil burning [12] which has time wait for the flame to range from 3.6 to 4.4 seconds (Figure 1 (a)) then the dammar resin has a more flammable property than jatropha oil.

**Figure 4.** Effect of the dammar resin mass on combustion time.

In dammar resin combustion with a material mass of 0.02 to 1.0 grams, it can be obtained the results in the form of dammar resin mass relation (g) with the length of combustion time (s) can be
seen in Figure 4. It can be seen that the relation of the dammar resin mass and combustion time is
directly proportional and forms a linear line with the equation of the line as follows:
\[ Y_t = 87.64 \cdot X_w + 1.373 \]  

From the results in Figure 4, it is calculated the relationship of the mass of the material with the
rate of mass burning which can be seen in Figure 5. The figure shows the relationship of the mass of
the material with the burning rate in the form of parabolic. At the beginning of the test, there is an
increase in the mass burning rate, the greater the mass of material increases the burning rate of the
mass becomes smaller. This shows that one day the change in mass of material does not affect the rate
of mass burning. In the figure the resulting graph forms the following curved line equation:
\[ Y_{vm} = -0.497 \cdot X_w^2 + 0.099 \cdot X_w + 0.004 \]  

**Figure 5.** Effect of dammar resin mass on burning rate.

**Figure 6.** Effect of dammar resin mass on flame distribution rate.
The burning rate of dammar resin can also be described by the relationship of the initial diameter of the dammar resin to the flame distribution rate (mm²/s) as shown in Figure 6. It was obtained the dammar resin diameter value (mm) and the flame distribution rate (mm²/s) using the following equation:

\[ X_D = 2^{\frac{3}{2}} \frac{3}{4\pi} \frac{X_w}{\rho} \]  \hspace{1cm} (4)

\[ Y_D = \frac{\pi X_D^2}{4.t} \]  \hspace{1cm} (5)

In Figure 6, it can be seen that the relationship of the initial diameter and flame distribution rate is inversely proportional and parabolic in shape with the equation of the line is:

\[ Y_{vd} = -0.051.X_D^2 + 0.306.X_D + 2.368 \]  \hspace{1cm} (6)

In Figure 6, it shows that the larger the initial diameter of the dammar resin, the flame distribution rate (mm²/s) is slower. In combustion with a larger diameter, the surface area of the recipient of the flame energy is also greater. With the increased surface area of the recipient of the flame energy, the rate of spread of the flame is slower. The same tendency is also generated in the combustion of jatropha oil [12] as shown in Figure 1 (b) where the greater the diameter of the droplet, the flame distribution rate (mm²/s) will be smaller. In dammar resin combustion with a material mass of 0.02 grams (equivalent to 3.28 mm diameter) the flame distribution rate (mm²/s) is in the range of 2.62 - 3.44 mm²/s (figure 6), when compared to the oil burning distance [12] which has a flame distribution rate ranging from 1.6 - 2.9 mm²/s (figure 1 (b)) then the dammar resin has a flame distribution rate that is faster than jatropha oil.

4. Conclusions
Based on the results of the experiments was conducted, it can be concluded that:
1. The mass relationship of dammar resin material (g) to the ignition delay (s) is expressed by the equation \( Y_I = -170.8.X_D^2 + 8.258.X_w + 1.631 \).
2. The mass relationship of dammar resin material (g) with the duration of combustion time (s) is expressed by the equation \( Y_t = 87.64.X_w + 1.373 \).
3. The mass relationship of dammar resin material (g) to the burning rate (g/s) is expressed by the equation \( Y_v = -0.497.X_D^2 + 0.099.X_w + 0.004 \).
4. The relationship of the initial diameter of dammar resin (mm) to the flame distribution rate (mm²/s) is expressed by the equation \( Y_v = -0.051.X_D^2 + 0.306.X_D + 2.368 \).

5. References
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