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Effects of the Addition of Coconut Shell Oil on Diesel Engine Performance: An Experimental Study

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Abstract

Biodiesel is one of the efforts to reduce dependence on fuel oil developed as an environmentally friendly alternative fuel in Indonesia. The addition of coconut shell oil will change the biodiesel properties and engine performance. This study aims to determine the physical properties and performance of fuel in diesel engines due to the addition of coconut shell oil. Several methods were applied to test the physical properties of biodiesel, namely: viscosity, density, cetane number, and calorific value. Meanwhile, the parameters for engine performance testing include torque, power, and specific fuel consumption. Biodiesels used were CS-20 and CS-40 for physical properties tests, and CS-10, CS-15, and CS-20 for engine performance tests. The results found that CS-20 had density of 842 kg/m^3, kinematic viscosity of 3.958 mm^2/s, cetane number of 62.4, flash point of 305.06°C, and heating value of 43,681.72 kJ/kg. For CS-40, the density was 867 kg/m3, the kinematic viscosity was 1.773 mm^2, and the calorific value was 43,390.74 kJ/kg. Based on the results of the diesel engine performance test, the highest torque value was 31.487 Nm on Dexlite at 967 rpm rotation with a mass of 9.51 kg, while the highest power was 4.021 kW on Dexlite at 1752 rpm rotation and torque of 21.919 Nm. The best specific fuel consumption on Dexlite at 3563 rpm rotation used 0.527 liters/kWh. In conclusion, the addition of coconut shell oil to Dexlite reduces energy as the calorific value decreases. Furthermore, it is proven that due to the addition of coconut shell oil, the engine performance is decreasing.

Keywords:
biodiesel, coconut shell, pyrolysis, torque, power.

1 Introduction

Biodiesel is a renewable energy source that becomes an alternative to help overcome the growing need for diesel fuel or diesel oil in Indonesia.

Biodiesel is a vegetable oil used as a renewable fuel. It can be easily processed, has flat price stability, does not endanger the environment with any pollution, and is naturally easily biodegradable (Wijawa, 2016). Used cooking oil can be utilized for the manufacture of biodiesel which provides several advantages. One of which is reducing daily waste in household or food industry and reducing the production of biodiesel fuel so its price is below that of pure vegetable oil [1]. Apart from used cooking oil, biodiesel can also be obtained from palm oil. Palm oil is defined as a type of vegetable oil that contains fatty acids at the C14-C20 carbon chain, so the opportunity to develop it as a feedstock for biodiesel is very high. In addition, there is coconut shell oil which has the property of absorbents of impurity materials. Or, kepayang oil which is added to the diesel engine fuel [2].

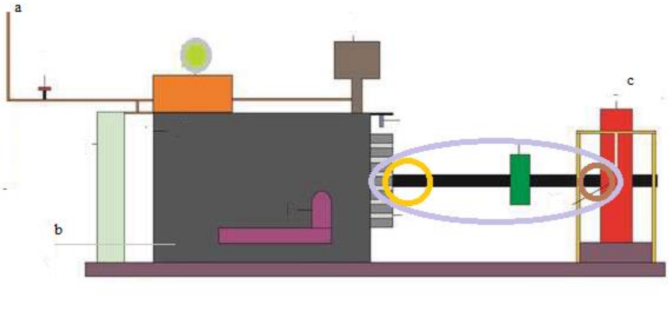
Liquid Smoke of Coconut shell is produced from condensation from the pyrolysis process in which the steam from the combustion of the coconut shell is either directly or indirectly accommodated in a container. During the combustion, the coconut shell undergoes *pyrolysis* that produces a mixture of chemical compounds which is dominated by phenols, carbonyls, alcohols, hydrocarbons, and others[3]. The characteristic of the lowest grade liquid smoke or the one without distillation is that it contains benzo alpha pyrene compounds with a value of 8.451 ppb [4]. In another study, liquid smoke of 100 ml had a pH characteristic of 0.596, a viscosity of 1780 CPs and a density of 0.343 g/cm^2 [5] .

Based on the research [6], it was concluded that the effect of the addition of methanol had a noticeable impact on the physical condition of the fuel. In accordance with the research (Yustia, et al., 2020), it was states that activated charcoal (coconut shell) had a high content of phenols and methanol. In the research [1], the viscosity value increased as the percentage of biodiesel from used cooking oil was also added with a maximum value of 5.62 CSt [7].

The mixing resulted in changes in both the physical properties and chemical properties of the biodiesel. The more mixture of coconut shell oil, the more the content of *aldehydes* and *phenol* increased, so that the fuel mixture will be flammable and not produce the energy required. Diesel-engine testing of biodiesel with the mixture of coconut shell oil, according to [8], enhanced diesel engine performance and increased the SFC. In addition, it is also very safe to use to enhance engine performance and reduce emissions without changing or modifying the diesel engine. During its development, the added coconut shell oil has had new biodiesel physical properties that can be sought. A comparison of the physical properties of Dexlite, CS-20, CS-40 and coconut shell oil will be carried out.

2 Research Methods

The performance testing of diesel engines was conducted using a diesel engine connected with *dynotest* type *prony brake* as in Fig. 1. A diesel engine of the DWP50 model (170F) was used in the study with a capacity of 4.1 kW. Performance data in the form of power, torque, and engine speed were obtained from the dynamometer prony brake.

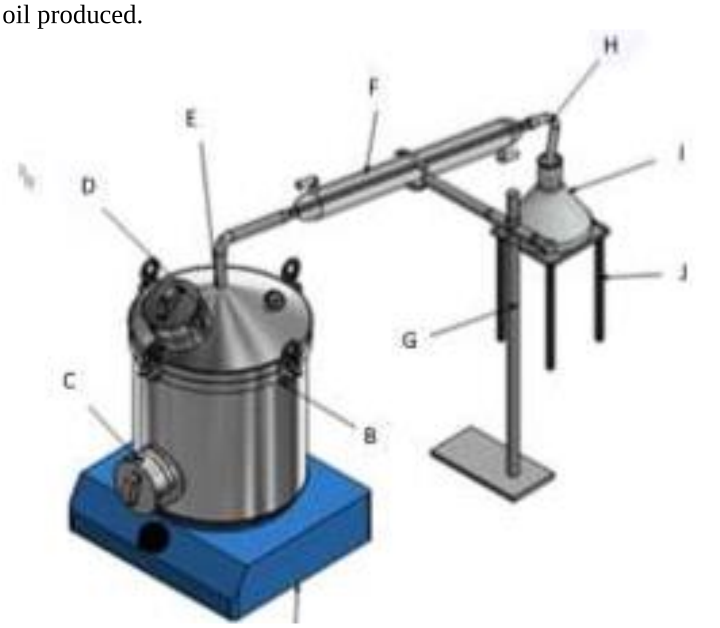


a.Fuel system b. Engine c. Dynamometer
Fig. 1. Testing Set-up

2.1 Fuel

Dexlite type fuel is the main fuel material of this test machine. The addition of coconut shell biodiesel was intended to find out the performance characteristics of such machine. The coconut shell oil used was a pyrolysis product. The pyrolysis process began with cleaning the coconut shell from remnants of the coir and drying it in the sun. Sodium *thiosulfate* ($Na_2S_2O_3$), potassium *iodide* (KI), amylum indicator, and Aquades were added as absorbers of moisture content in the process [9]. The pyrolysis process was carried out for 7 hours with a temperature of 275 °C with the *pyrolysator* device as in Fig. 2.

After the pyrolysis process had been completed, it was followed with the test of the physical properties of coconut shell oil. This test was conducted to determine the value of the density, viscosity, *Cetane* number, and the flash point of the coconut shell oil produced.



d.Outlet, e.Reactor, f.Inlet, g.Condenser, h.Statip, i.Adapter, j. Erenmeyer, k.Leg

Fig 2. Pyrolysator [10]

Some of the biodiesel mixtures used included those presented in Table 1 with the types used for the test of the physical properties and the performance of the machine.

Table 1. Biodiesel used

Name	Composition
Dexlite / B30	100% Dexlite
CS-10	90% Dexlite 10% Coconut Shell Oil
CS-15	85% Dexlite 15% Coconut Shell Oil
CS-20	80% Dexlite 20% Coconut Shell Oil
CS-40	60% Dexlite 40% Coconut Shell Oil

2.2 Testing Steps

2.2.1 Material mixing

The mixing of Dexlite with coconut shell oil into biodiesel was carried out according to predetermined materials.

2.2.2 Physical-Properties Test

The test of physical properties was carried out using several methods, including the fuel cetane number of ASTM D613 method with a *Cetane*-rating-unit device. The next, a picnometer was used to test the density of the fuel. The test of fuel viscosity conducted using ASTM D445 method with a kinematic-viscometer device. The last test of physical properties was the calorific value of the fuel using a calorimeter bomb with an automatic isoperibol type 6400 from PARR. All tests were carried out at the UPT Integrated Laboratory of Diponegoro University.

2.2.3 Diesel-Engine-Performance Testing

The test was carried out at the Energy Laboratory of Wahid Hasyim University Semarang with the following steps:

1) Preparing the engine and fuel;
2) Putting Dexlite fuel into the fuel measuring cup;
3) Starting the Engine;
4) Turning the brake lever to give a certain load to the brake disk and recording the load;
5) Reading the *forcemeter* or the hanging scales as the mass given to the disk and recording it;
6) Measuring the rotation of the engine shaft using a tachometer and recording it;
7) Allowing 20 seconds for the combustion process and the decrease of the fuel;
8) Adding a load on the engine by turning the brake lever and repeating steps 5 and 6;
9) Repeating the experiment using another fuel.

2.3 Data Analysis

The fuel mixed with coconut shell oil was tested on a diesel engine using the following parameters and equations [11]:

2.3.1 Torque

$$T = F.r \tag{1}$$

where T = Torque [N.m], F = Working force [N] and r = Loading distance [m].

2.3.2 Power Calculation

$$P = \frac{T.2\pi.n}{60} \tag{2}$$

Where, P = Shaft Power [kWatt], T = Torque [N.m], n = Shaft rotation [rpm]

2.3.3 Specific Fuel Consumption

$$SFC = \frac{\dot{mf}}{P} \tag{3}$$

Where: SFC = *specific fuel consumption* [g/kWh or liter/kWh], mf = fuel consumption [cm^3/s], P = shaft power [kWatt]

3 Results and Discussion

The largest density value obtained was 1018 kg/m^3 which was from coconut shell oil. The addition of coconut shell oil to Dexlite gave different densities as shown in Fig. 3. The addition of coconut oil increased the density value of the fuel. The more coconut oil added to Dexlite, the more density of the fuel was obtained. In accordance with the study, activated charcoal (coconut shell) had a high phenol and methanol content [12].

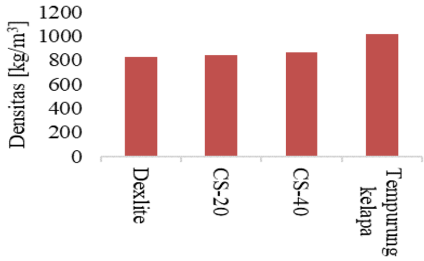


Fig. 3. Fuel density value

3.1 Fuel Viscosity

The greatest viscosity value obtained was 4.124 mm^2/s which was from coconut shell oil, as shown in Fig. 4. The addition of coconut shell oil to Dexlite gave a change in viscosity.

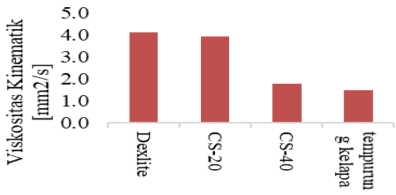


Fig 4. Score viscosity kinematics

In Aziz's research (2010), the viscosity value increased in accordance with the percentage of biodiesel from used cooking oil added with a maximum value of 5.62 CSt [1]. So that the more coconut oil added to Dexlite, the more viscosity of the fuel was obtained in accordance with the ratio concentration of Dexlite and coconut shell oil.

3.2 Cetane Number of The Fuel

The highest cetane number obtained was 69.8 which was from the CS-25 sample. And the lowest cetane number obtained was 51.5 which was from the the CS-10 sample. According to the results, the cetane number increased as the coconut shell oil was added to become biofuel, as shown in Fig. 5. The flash-point test of the fuel was conducted by adding a mixed volume (fig 6).

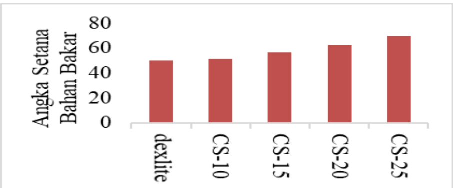


Fig 5. Cetane number in the sample

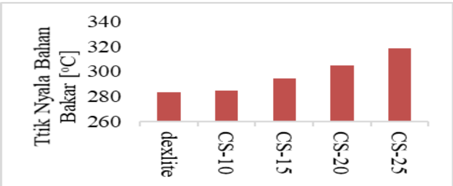


Fig 6. Flash point of The Fuel

The flash-point test of the fuel was conducted by adding a mixed volume. The flash point of the CS-15 was 294.29 ^{o}C, and the flash point of CS-20 was 305.02 ^{o}C. In the last test on the CS-25, its flash point was 318.78^{o}C.

3.3 Calorific Value of The Fuel

Calorific value of the fuel was tested with a PARR 6400 calorimeter bomb. The test results are shown in Fig. 7. The addition of coconut shell oil caused the decrease of calorific value. It was seen with the same volume concentration that CS-20 samples had a lower calorific value than Dexlite with a decrease of 95.1 kJ/kg. In the CS-40 sample, it decreased more noticeably and it was lower than that of Dexlite and of CS-20. The difference of calorific value between CS-40 and CS-20 was 291 kJ/kg, while and the difference between CS-40 and Dexlite was 386.1 kJ/kg.

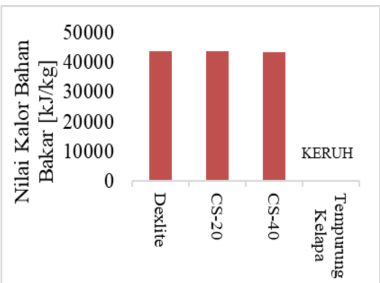


Fig 7. Calorific Value of The Fuel

3.4 Analysis of Physical Properties

The changes will affect the quality of the fuel produced. It can be explained from the viscosity value that the mixing of Dexlite with coconut shell oil reduces the viscosity of Dexlite fuel. The density of the fuel tested will increase as the coconut shell oil mixture increases, approaching the density value of coconut shell oil.

The mixing of coconut shell oil on Dexlite affects the cetane number. Every addition of the coconut shell oil mixture adds the cetane number to the fuel. The more coconut shell oil in the mixture, the more contents of aldehyde and phenol increase, so that the fuel mixture will be flammable and not produce the energy needed. Meanwhile, the more volume composition of coconut shell oil, the greater flash point of the fuel is.

The test results show that the calorific value was further reduced with the volume addition of the coconut shell oil. A decrease in calorific value means that coconut shell oil degrades the quality of fuel in terms of energy produced.

3.5 Performance of diesel engines with mixed biodiesel fuel

Fig 8. shows the relation curve of engine speed to power and torque generated.

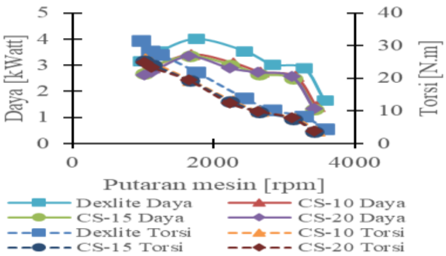


Fig 8. The relation curve of rotation to power and torque

Based on the comparison of power and torque with the addition of coconut shell oil, the power generated decreases as the concentration of coconut shell oil increases. Further, in the braking process, when there is a decrease in the rotation of the engine shaft, the power generated value increases from the initial start, and then it decreases close to stopping, the power value decreases. The torque result is based on the difference in the fuel used. The concentration addition of coconut shell oil to Dexlite reduces the torque generated. This is because the torque is affected by the mass of the load which decreases as the concentration of coconut shell oil is added to Dexlite, so that the torque decreases as well. This also results in the power generated, in accordance with the relation of torque and power, which is directly proportional to the increase in torque due to the braking process, so the power increases as well.

Fig. 9 shows the relationship curve between the engine speed to the specific fuel consumption and power of the diesel

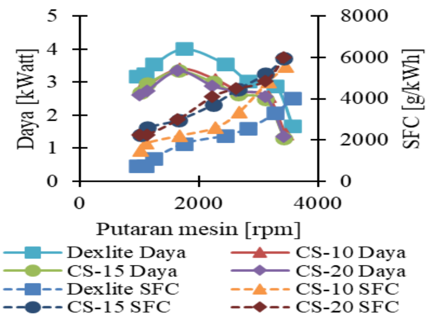


Fig 9. Relation of engine speed to power and specific fuel consumption

Fig. 9 presents a relationship curve between the engine speed to the specific fuel consumption and power of the diesel engine tested. The results show that as the power increases due to the braking process and the rotation decrease, the fuel consumption decreases. Comparisons of different fuels resulted in different fuel consumption in the tests. As the concentration of coconut shell oil increased in Dexlite, the value of fuel consumption increased up to CS-15. Meanwhile, in CS-20 there was a decrease in the value of fuel consumption used. However, in the CS-20 the specific fuel consumption value was greater than Dexlite. The relation between torque and fuel consumption in the test results showed that in several types of fuel the torque value increased due to the braking process that lower the engine speed, and the specific fuel consumption required decreased further.

Based on the data and graph above, the performance parameters of the diesel engine were obtained. The highest torque value obtained was 31,487 N.m which was from Dexlite, for a shaft rotation of 967 rpm and a load mass of 9.51 kg. The highest Power Value at Dexlite engine shaft rotation was 1752 rpm and the torque was 21,919 N.m with a value of 4,021 kWatts. The best specific fuel consumption was obtained from Dexlite with a rev of 3563 rpm using 0.527 liters/kWh. In other words, the addition of coconut shell oil to Dexlite degraded engine performance at specific torque, power, and fuel consumption parameters. According to (Harsono & Siregar, 2015), excessive use of biodiesel from coconut reduces the quality of fuel to be tested on the engine for the best value obtained at a concentration of 70% diesel mixture and 30% coconut biodiesel.

Due to the addition of coconut shell oil, the percentage of diesel engine performance, in terms of power for CS-10, decreased by 12.1%, then decreased by of 15.3% from Dexlite for CS-15, and decreased by 17.5% from Dexlite for CS-20 fuel type.

4 Conclusion

Based on the test of physical properties of the fuel with the addition of coconut shell oil, it can be concluded that:

1. The results of testing the physical properties of the fuel that addition of coconut shell oil has an impact on the fuel energy produced due to the decreasing calorific value.
2. The addition of coconut shell oil to Dexlite degrades the engine performance at torque parameters, power, and specific fuel consumption.

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