EVALUATION OF DIESEL ENGINE AND FARM TRACTOR PERFORMANCE POWERED BY COCODIESEL (CME)

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ABSTRACT

Playing its role as a developing country, Indonesia also facing the energy crisis, therefore, Indonesian government strongly promotes the utilization of alternative fuels. As an agricultural country, Indonesia indeed has a great potential of producing vegetable oils such as palm oil, Jatropha oil, coconut oil, etc., which are renewable raw materials for biodiesel production. The utilization of coconut oil as the raw material for cocodiesel is very prospective, because Indonesia has 3.9 million ha of coconut tree, which is the largest in the world, and spreading along the coastal area. Applying cocodiesel as the alternative fuel for agricultural machinery and fishing vessel become very valuable, especially in the remote area where a huge amount of coconut oil source is available while the price of petroleum diesel fuel is very high due to excessive transportation cost. This research is aimed to evaluate the technical features of the application of cocodiesel as the alternative fuel for stationary diesel engine as well as for agricultural tractor. As the results of this study, it was found that the diesel engine could run smoothly with all blending ratio of cocodiesel fuel without notable problems. The engine performance characteristics of stationary diesel engine by using cocodiesel blended fuels are closed to those of petroleum diesel fuels. However, the maximum brake horse power value of engine running on pure cocodiesel (B100) is 10.67% lower than that for petroleum diesel. It was also revealed that globally regulated emission; CO and HC values of engine running on cocodiesel blended fuels are noticeably lower than that for petroleum diesel. Related results were also observed in the application of cocodiesel for agricultural tractor. The tractive performances of tractor using cocodiesel showed similar behaviour to those of petroleum diesel, however, it was revealed that the drawbar power becomes lower with the increase of cocodiesel composition in the fuel.

Keywords: *cocodiesel, engine performance, emission, tractor drawbar performance*

INTRODUCTION

Recently, there are many studies on alternative fuel which are driven by the need for new energy sources and the need to protect the environment. Biodiesel is a diesel replacement fuel that is manufactured from vegetable oils, recycled cooking greases or oils, or animal fats. The word biodiesel in this paper refers to the pure fuel B100 that meets the specific biodiesel definition and standards approved by ASTM International. A number following the "B" indicates the percentage of biodiesel in a gallon of fuel, where the remainder of the gallon can be No. 1 or No. 2 diesel fuel. Nowadays, in developed countries blending of 20% biodiesel with 80% diesel fuel (B20) are commonly used in most applications that use diesel fuel. Higher blend levels, such as B50 or B100, require special handling and fuel management and may require equipment modifications such as the use of heaters or changing seals and gaskets that come in contact with the fuel to those compatible with high blends of biodiesel. The level of special care needed largely depends on the engine and vehicle manufacturer.

Playing its role as a developing country Indonesia also facing the energy crisis, therefore, Indonesian government started to promote the use of alternative fuels. Indonesia indeed has a lot of plant derived oil such as palm oil and coconut oil. However, palm oil and coconut oil is categorized as edible oil and its conversion to biodiesel still debatable (Grimwood, 1975). Since the price of cooking oil made from palm oil are cheaper than cooking oil made from coconut oil, so, the coconut based cooking oil are less preferred in the market. Therefore, recently, there a huge number of oil resources from coconut are might be abandon. So, the aims of this research is to investigate the technical aspects of the potential of coconut oil as the biodiesel fuel for diesel engine

OBJECTIVE

This research is aimed to evaluate the performance of diesel engine as well as the properties of emission gas in applying coconut oil based biodiesel fuel. The result of this research was compared to the performance of diesel engine by using petroleum based diesel fuel.

METHODOLOGY

This research was divided in to main two steps. In the first step, cocodiesel was applied to run a small diesel engine in order to evaluate the effect of cocodiesel blended fuel to the engine performance and emission. The second step was the application of cocodiesel for an agricultural tractor and evaluates its drawbar performance as well. First step of this research was done at Faculty of Bioresources, Mie University, Japan, while the second step was done at Bogor Agricultural University, Indonesia

Material

The material will be used in this research is the cocodiesel (Coco Methyl Ester, CME) which was processed from Indonesian commercial coconut oil. This cocodiesel was made by mean of transesterification with catalyst method using potassium hydroxide and methanol. In addition, Japanese commercial petroleum diesel fuel (BO) will also be used for the comparison purpose. The cocodiesel fuel was blended with petrol diesel fuel at the level of 20%(B20), 40%(B40), 60%(B60), 80%(B80) and 100% cocodiesel fuel (B100). The picture of fuel used in the experiment is shown in Figure 1.

Figure 1. Blended fuels used in the experiment

Experimental Apparatus

In the first step of this research, a commercial four stroke, air cooled diesel engine was used for the experimental test. The engine capacity is 0.199 litre with maximum power output 3,1 kW / 1800 rpm. The tested engine was connected to an electric AC dynamometer (Toyo Denki Seizo) and the engine torque was acquired by a balance with constant arm. The engine rotational speed was measured by digital tachometer (Shimpo DT-201). The fuel consumption was obtained by volumetric method where an automatic digital timer was used to measured elapse time for a certain volume of fuel. The digital exhaust gas analyzer (Horiba MEXA-554J) was used for measurement of the emission gas.

In the second step, a four wheel drive small tractor was used for evaluating the tractive performance of tractor powered by cocodiesel. The maximum engine power of the tested tractor was 14 hp/2800 rpm. In order to provide load to the tested tractor, a bigger size tractor was towed by the tested tractor while applying its engine brake. The drawbar pull was sensed by a load cell and recorded by a handy strain meter. Other parameters i.e. forward speed and wheel slippage were also measured accordingly.

Test Procedure

In the first step of this research, the Japanese commercial petroleum diesel fuel (B0) was used to power the diesel engine and the parameters of engine speed, engine torque, fuels consumption and exhaust gas emission i.e. CO, HC and CO_2 were measured at full throttle condition, correspondingly. Several series of test were done by using cocodiesel fuel blended with petrol diesel fuel at the level of 20% (B20), 40%(B40), 60%(B60), 80%(B80) and 100% cocodiesel fuel (B100). These ratio was made in order to evaluate the effect of cocodiesel content in the fuel (Machacon et al., 2001). The ambient temperature and atmospheric pressure were measured at the beginning and at the end of each test run for power correction purpose (Hunt, 1995). All test runs were started with a 10 minutes warm-up period prior to data collection. The test were started at full throttle with maximum engine speed (1850 rpm), then gradually dropped down to minimum possibly measured engine speed (1100 rpm) by increasing the brake torque on the dynamometer. For each speed, reading or data acquisition were taken correspondingly. The setup of engine performance test is shown in Figure 2.

Figure 2. Setup of engine performance test

The power delivered by the engine were calculated by Equation (1) (Goering, 1986):

$$P_o = \frac{3.14 * n * C}{30000} \quad \text{..........(1)}$$

being : P_o : brake horse power (kW),
n : engine rotational speed (rpm),
C : torque (Nm).

The specific fuel consumption which is the ratio between fuel consumption and the power supplied at the same time by the engine is defines as Equation (2):

$$q_s = \frac{q_{mf}}{P_o} \quad \text{..........(2)}$$

being: q_s : specific fuel consumption (kg/kWh),
q_{mf} : fuel consumption per hour (kg/h),
P_o : brake horse power (kW).

The diesel engine performance can be shown in term of relationship between engine torque, engine power and specific fuel consumption with engine speed (Ozkan et al., 2005). The characteristics of emission can be expressed in term of CO_2, CO and HC content in exhaust gas at different engine load (Suryanarayanan et al., 2006).

In the second step, the evaluation of the tractive performance of agricultural tractor was carried out on the standard concrete test road. The arrangement of the tractive performance test is shown in Figure 3. The tested tractor was driven straight ahead using L2 transmission gear. Load tractor was used for gradually increase the load applied to the tested tractor. The measured parameters on tractive performance test were drawbar pull, actual forward speed, and wheel slippage. Based on the above parameters, drawbar power, and coefficient of traction ratio were calculated for showing the characteristics of tractive performance.

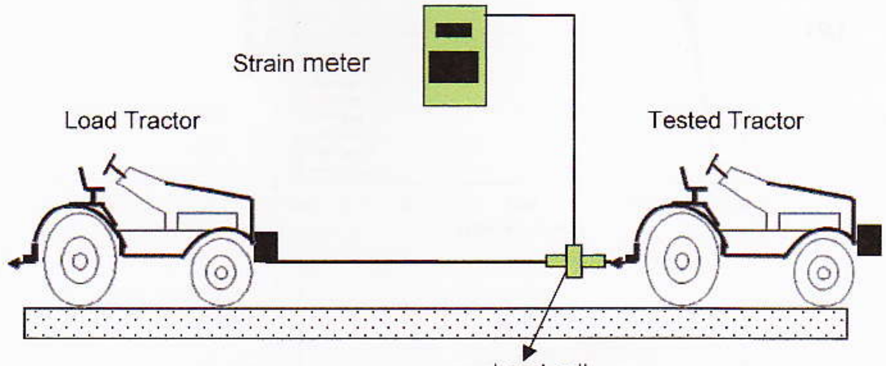


Figure 3. Setup of tract ormance test

RESULTS AND DISCUSSION

Diesel Engine Performance

The results of diesel engine performance test in term of relationship between engine torque, power and specific fuel consumption with engine speed are shown in Figure 4 (a), (b) and (c). Figure 4(a) shows the variation of engine torque with the engine speed. The torque values for each test runs with different blending ratio of fuel show similar behaviour as the common engine torque performance graphs. The maximum torque values reached at around 1300 rpm of engine speed for all fuels. However, the engine torque reduces gradually as the blending ratio of cocodiesel increase. The maximum engine torque by using petroleum diesel fuel (B0) was found to be 19.4 Nm at 1300 rpm while for 100% cocodiesel fuel (B100) was 18.1 Nm at 1300 rpm. This result indicated that the maximum engine torque by applying 100% cocodiesel (B100) is 6.57% lower than that with petroleum diesel (B0).

The variation of engine brake horse power for each fuel is shown in Figure 4(b). The maximum power reached at 1700 rpm of engine speed, and similar to the torque performance, the petroleum diesel fuel (B0) has the greatest power values. The value of brake horse power decrease as the ratio of cocodiesel fuels increase. The maximum brake power by using petroleum diesel fuel (B0) was found to be 3.13 kW at 1700 rpm while for 100% cocodiesel fuel (B100) was 2.80 kW at 1700 rpm. This result indicated that the maximum engine brake power by applying 100% cocodiesel (B100) is 10.67% lower than that with petroleum diesel (B0). However, it can be seen from the power performance graphs that the gap of power loss becomes smaller when the load increased.

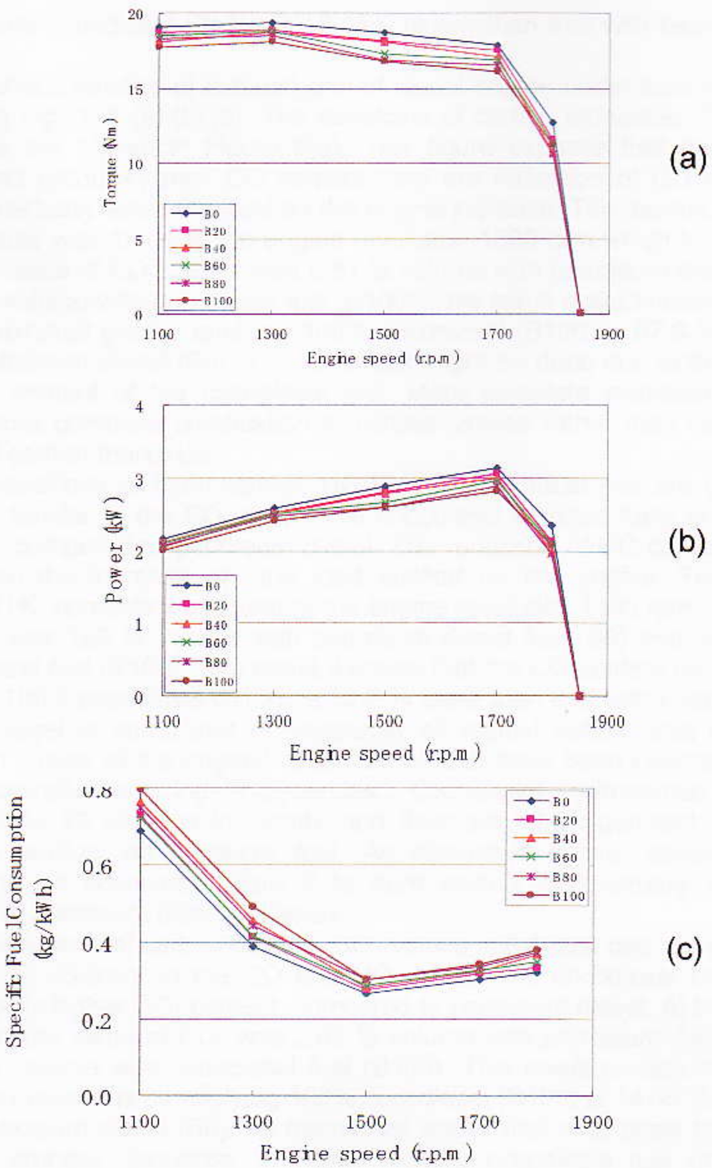


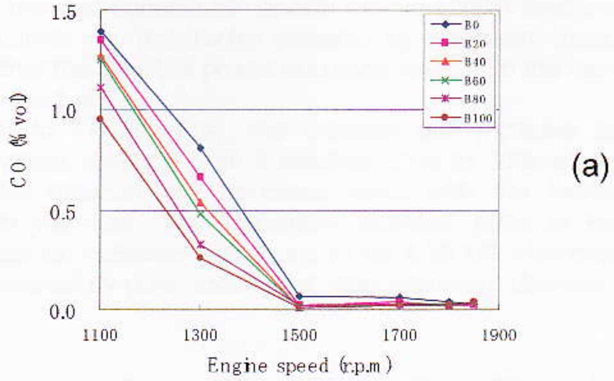
Figure 4. Diesel engine performance graphs

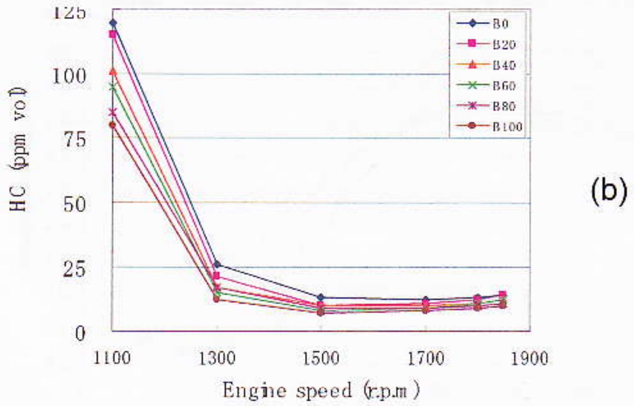
The variation of specific fuel consumption (SFC) of these fuels are presented in Figure 4(c). It is revealed that as the consequences of the reduction of the brake power values, the SFC values of cocodiesel blended fuels are higher than that with petroleum diesel fuel (B0). The minimum SFC value with petroleum diesel fuels (B0) was 0.266 kg/kWh at 1300 rpm, and with cocodiesel fuel (B100) 0.301 kg/kWh at 1300 rpm. This result disclose that at the minimum curve of SFC, the SFC by applying 100% cocodiesel (B100) is 13.46% higher than that with petroleum diesel (B0).

The characteristics of exhaust gas of diesel engine under load condition are presented in Figure 5 (a),(b),(c). The variations of carbon monoxide, CO values in exhaust gas are shown in Figure 5(a). This figure exposes that the cocodiesel blended fuels produce lower CO content, and the reduction of CO contents are reduced remarkably when the load on the engine increase. The maximum reduction of CO contents was found at the engine revolution 1300 rpm which is at maximum torque. The value of CO content was 0.81 % volume with petroleum diesel fuel (B0) and 0.26 % volume with cocodiesel fuel (B100). This result make known that the CO content on exhaust gas by applying 100% cocodiesel (B100) is 67.9 % lower than that with petroleum diesel (B0). This reduction might be done due to the increasing the oxygen content of the cocodiesel fuel. More complete oxidation of the fuel results in more complete combustion to carbon dioxide rather than leading to the formation of carbon monoxide.

The variations of hydrocarbon, HC values in exhaust gas are presented in Figure 5(b). Similar to the CO values, the cocodiesel blended fuels produce lower HC content, compared to petroleum diesel. The reduction of HC contents tends to increase with the increase of the load applied on the engine. The maximum reduction of HC contents was found at the engine revolution 1100 rpm. The value of HC content was 120 % volume with petroleum diesel fuel (B0) and 80 % volume with cocodiesel fuel (B100). This result disclose that the CO content on exhaust gas by applying 100% cocodiesel (B100) is 33.3 % lower than that with petroleum diesel (B0). Cocodiesel is comprised of vegetable oil methyl esters, that is, they are hydrocarbon chains of the original vegetable oil that have been chemically split off from the naturally occurring "triglycerides". Cocodiesel hydrocarbon chains are generally 16 to 20 carbons in length, and they are all oxygenated at one end, making the product an excellent fuel. As discussed above, several chemical properties of the cocodiesel allow it to burn cleanly and actually improve the combustion of petroleum diesel in blends.

The variations of carbon dioxide, CO_2 values in exhaust gas are presented in Figure 5(c). In contrary to the CO and HC values, the cocodiesel blended fuels produce slightly higher CO_2 content, compared to petroleum diesel. At the maximum brake power, the value of CO_2 was 2.52 % volume with petroleum diesel fuel (B0) and 2.89 % volume with cocodiesel fuel (B100). This result reveals that the CO_2 content on exhaust gas by applying 100% cocodiesel (B100) is 14.68 % higher than that with petroleum diesel (B0). As mentioned above that cocodiesel fuel improves combustion process, therefore, in case of using cocodiesel fuel or cocodiesel blended fuel, the CO_2 value in exhaust gas increased instead of
unburned HC and CO emission. Although the tailpipe carbon dioxide, CO_2 is higher for cocodiesel fuel operated engines, cocodiesel fuel provides a distinct advantage in a full lifecycle assessment in which emissions from fuel production and fuel use are considered. In the case of plant-based cocodiesel, carbon dioxide uptake by plants during respiration offsets the CO_2 emission. It is reported by USDE that by lifecycle analysis the total reduction of CO_2 was 78 % when using soybean cocodiesel.





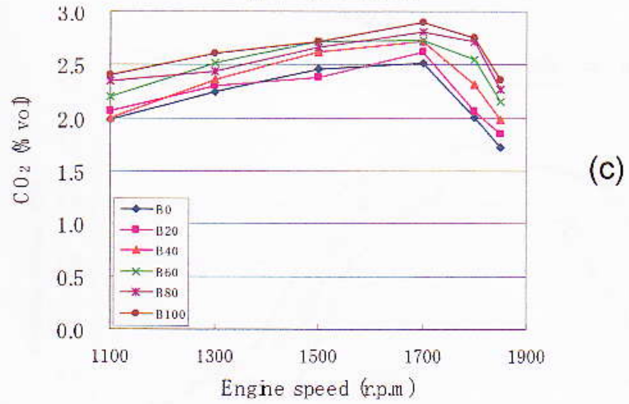


Figure 5. Characteristics of exhaust gas

Tractor Tractive Performance

The results of tractive performance test which was done on concrete test road are shown in Figs. 6. Based on the trend line exposed in those graphs, it can be said that the characteristic of tractive performance curves for the tractor powered by cocodiesel or blended cocodiesel shown almost similar tendency with the tractive performance curves for the tractor powered by petroleum diesel fuel. However, it was revealed that the drawbar power becomes lower with the increase of cocodiesel composition in the fuel.

Referred to Figures 6(a), the drawbar pull increase drastically with the increment of wheel slippage until it reaches 25% to 30% wheel slip. The graphs shown that the drawbar pull becomes lower with the increase of cocodiesel composition in the fuel. The maximum drawbar pulls of tractor powered by petroleum diesel on concrete was found to be 4.58 kN. However, when the tested tractor was powered by pure cocodiesel, the maximum drawbar pull decreased up to 3.56 kN.

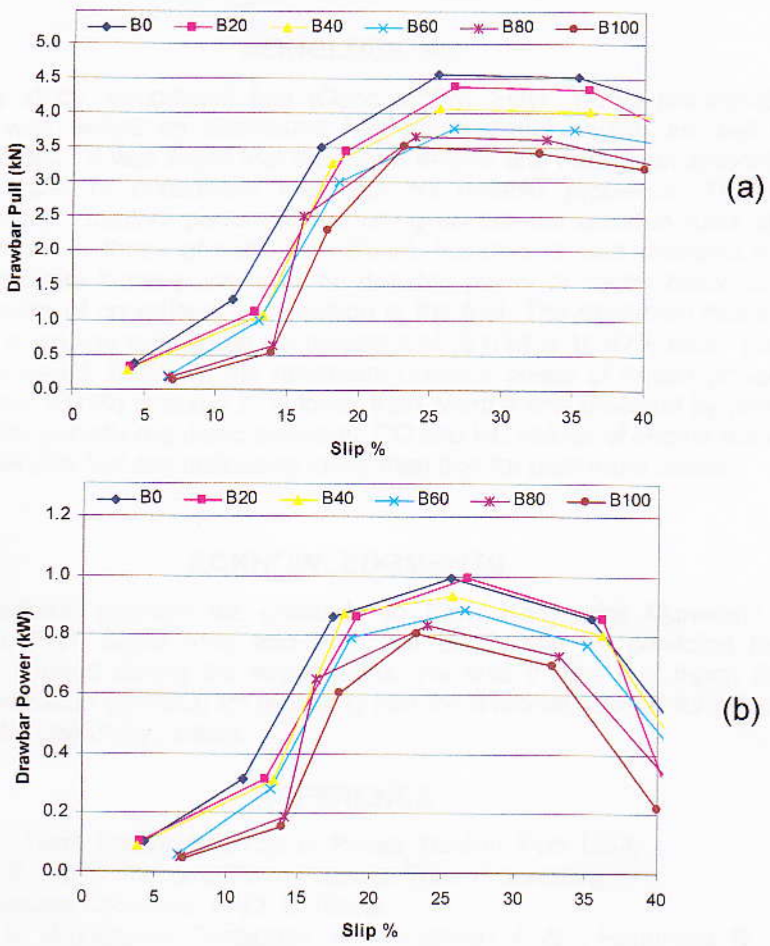


Figure 6. Tractive performance graphs on concrete test road

The drawbar power tends to increase as the wheel slip increase until it reaches at a maximum value at about 25% wheel slip as shown in Figure 6(b). Then, drawbar power decreased with the increase of wheel slip. The reason why this occurred is that the forward speed was decreasing while the drawbar pull was increasing slightly. The maximum drawbar power of tractor powered by petroleum diesel on concrete was found to be 1.06 kW. Similar with the trend of drawbar pull, the maximum drawbar power of tractor powered by pure cocodiesel decreased up to 0.82 kW. It means that the maximum drawbar power of tractor powered by pure cocodiesel (B100) is about 23% lower than when it was powered by petroleum diesel. The reason why the drawbar power of tractor powered by cocodiesel was lower than that by petroleum diesel is mainly due to the lower heat value of cocodiesel. It was reported by Hambali et al. (2007) that the heat value of cocodiesel and petroleum diesel are 32 MJ/l and 42 MJ/l, respectively.

CONCLUSIONS

In this study, cocodiesel fuel (Coco Methyl Ester, CME) processed from coconut oil was tested as alternative fuel for a diesel engine as well as an agricultural tractor . It was found that the diesel engine and tractor run smoothly with all blending ratio of cocodiesel fuel with no notable problems. The engine performance and tractive performances using cocodiesel blended fuels showed similar behaviour to those of petroleum diesel, however, it was revealed that the diesel engine brake horse power and the drawbar power of tractor becomes lower with the increase of cocodiesel composition in the fuel. The maximum brake horse power value of engine running on cocodiesel fuel (B100) is 10.67% lower than that for petroleum diesel. Similarly, the maximum drawbar power of tractor powered by pure cocodiesel (B100) is about 23% lower than when it was powered by petroleum diesel (B0).The globally regulated emission, CO and HC values of engine running on cocodiesel blended fuel are noticeably lower than that for petroleum diesel.

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