Effect of Blending Ratio of Cocodiesel (CME) on Diesel Engine Performance

Desrial
Faculty of Agricultural Engineering and Technology
Department of Mechanical and Biosystem Engineering
Bogor Agricultural University
Kampus IPB Darmaga, PO Box 220, Bogor 16002, Indonesia,

Abstract — Playing its role as a developing country Indonesia also facing the energy crisis, therefore, Indonesian government strongly promotes the utilization of biofuels. 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 producing biofuel susch as biodiesel. 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 fuel for stationary diesel engine. The biodiesel fuel used in this research was the cocodiesel which was produced from commercial coconut cooking oil. In order to evaluate the effect of cocodiesel on the engine, the cocodiesel was blended with petroleum diesel fuel at the level of 20% (B20), 40%(B40), 60%(B60), 80%(B80) and 100% cocodiesel (B100). 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.

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. Because plants produce oils from sunlight and air, and can do so year after year on cropland, these oils are renewable. Animal fats are produced when the animal consumes plant oils and other fats, and they too are renewable.

The word biodiesel in this report 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, kerosene, jet A, JP8, heating oil, or any other distillate 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. 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 study the effect of blending ratio of cocodiesel (CME) on the performance of diesel engine as well as the properties of its emission gas. The results of each blending ratio was compared to the performance of diesel engine by using petroleum diesel fuel.

METHODOLOGY

Material

The material used in this research was 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, commercial petroleum diesel fuel (B0) will also 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 Fig 1.

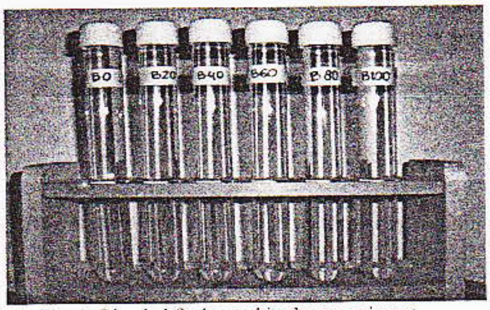

Fig. 1. Blended fuels used in the experiment

Experimental Apparatus

A commercial small air cooled diesel engine 3,1 kW /1800 rpm was used for the experimental test. The test engine was connected to the electric AC dynamometer (Toyo Denki Seizo) by using proper V-belts in order to apply load to the engine. The measurement of engine torque is carried out by means of a balance with constant arm. The engine rotational speed is measured by digital tachometer (Shimpo DT-201). The volumetric measuring method was chosen to measure the engine fuel consumption and an automatic digital timer was used to measured time for a certain volume of fuel. The standard exhaust gas analyzer (Horiba MEXA-554J) was used for measurement of the emission gas. The engine test bench lay out can be seen in Fig. 2.

Test Procedure

The 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. Then, 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). The ambient temperature and atmospheric pressure were measured at the beginning and at the end of each test run for power correction purpose. 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 r.p.m), then gradually dropped down to minimum possibly measured engine speed (1100 r.p.m) by increasing the brake torque on the dynamometer. For each speed, reading or data acquisition were taken correspondingly.

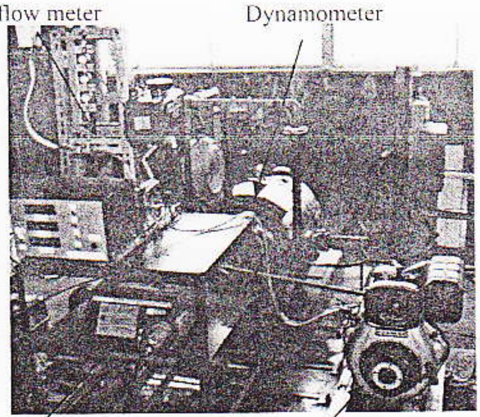

Fig. 2. Setup of engine performance test

The power delivered by the engine[1] were calculated by means of the Equation (1):

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

being : P_o : power (kW)
n : engine rotational speed (r.p.m)
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):

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

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

RESULTS AND DISCUSSION

Diesel Engine Performance

Fig. 3 shows the variation torque with the engine speed. The torque values for each test runs with different fuel show similar behavior as the common engine torque performance graphs. The maximum torque values reached at 1300 rpm of engine speed for all fuels. This figure shows the effect of cocodiesel blends with the petroleum diesel to the engine torque. The engine torque reduces gradually as the blending ratio of cocodiesel increase. This trend also similar with the previous research by using coconut oil[2]. 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 power values for each fuels is shown in Fig. 4. 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 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.

The variation of specific fuel consumption (SFC) of these fuels are presented in Fig. 5. 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).

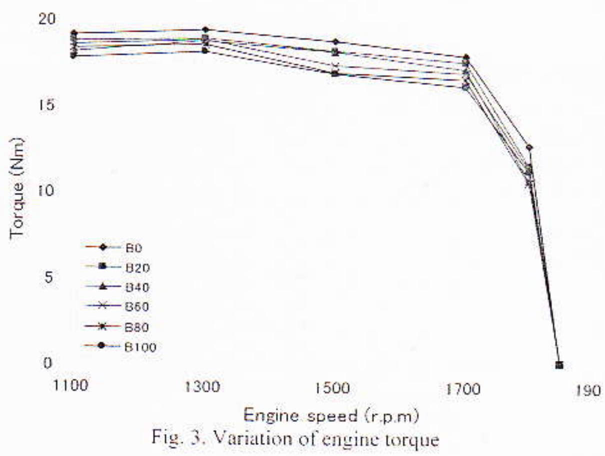

Fig. 3. Variation of engine torque

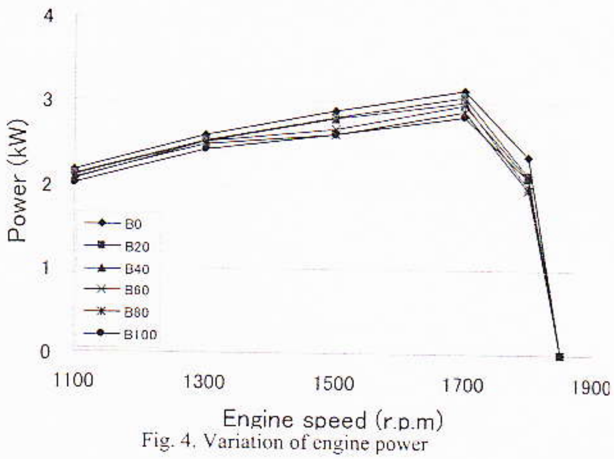

Fig. 4. Variation of engine power

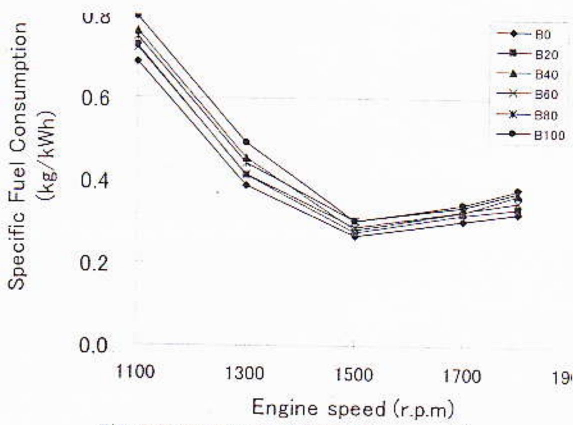

Fig. 5. Variation of specific fuel consumption

Emission of Diesel Engine

The variations of carbon monoxide, CO values in exhaust gas are shown in Fig. 6. 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.

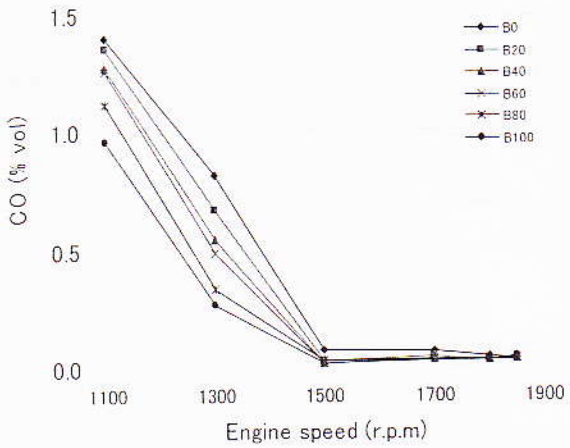

Fig. 6. Variation of CO content in exhaust gas

The variations of hydrocarbon, HC values in exhaust gas are presented in Fig. 7. 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"[3]. 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 Fig. 8. In contrary to the CO and HC values, the cocodiesel blended fuels produce slightly higher CO_2 content, compared to petroleum diesel. The similar condition also reported in the previous results [4][5]. 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 increase 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.

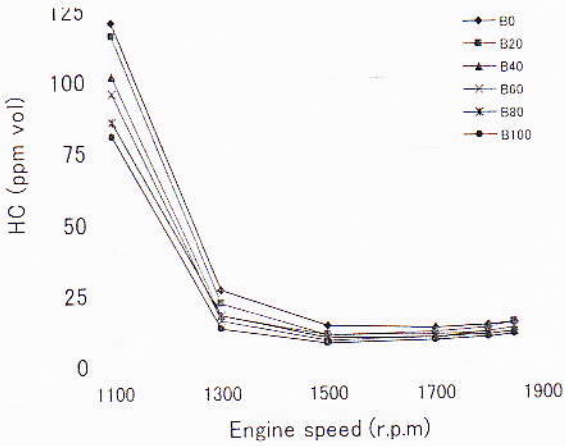

Fig. 7. Variation of HC content in exhaust gas

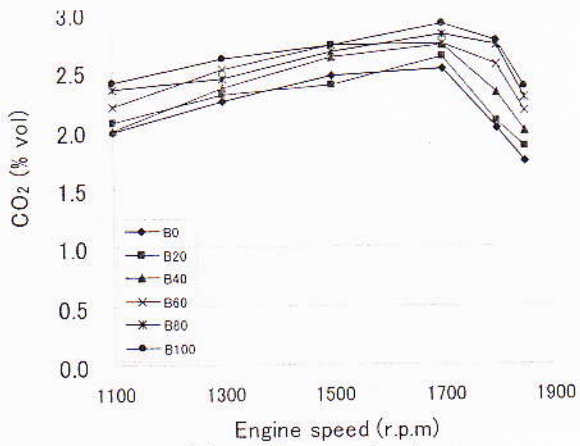

Fig. 8. Variation of CO_2 content in exhaust gas

CONCLUSIONS

In this study, cocodiesel fuel (coco methyl ester, CME) processed from coconut oil with different blending ratio were tested to run a commercial diesel engine. It was found that the diesel engine could run smoothly with all blending ratio of cocodiesel fuel with no notable problems. The engine performance by using cocodiesel blended fuels showed similar behaviour to those of petroleum diesel, however, it was revealed that the diesel engine brake horse power 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. However, the globally regulated emission, CO and HC values of engine running on cocodiesel blended fuel are noticeably lower than that for petroleum diesel. Considering the results of this research in term of engine power performance and its emission, so it is recommended that cocodiesel can be commercially used as alternative fuel for diesel engine.

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