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Effect of Addition of Spent Coffee Grounds Oil On the Performance of Diesel Engine

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Abstrak. *Energy demand has continued to rise since the industrial revolution and continues to increase as industry develops and population growth. About 80% of the world's energy is supplied by fossil fuels, which will be exhausted by the years to come. To solve this problem, the industries use waste vegetable oils and animal fats to produce biodiesel. Some also use non-edible waste as a biodiesel producer. Biodiesel can be produced from spent coffee grounds. The oil extracting is carried out using soxhlet and n-hexane which is purified using a rotary evaporator in the next move. Methyl esters are taken through the transesterification process. Methyl esters are mixed with diesel fuel. Then a characteristic test was conducted at Pertamina's Laboratory and performance test on ISUZU 4JA-1 OHV diesel engine using water brake dynamometer. The results of characteristics test of B10, B15, and B20 meet the requirements of the Directorate General of Oil and Gas Indonesia Number 28K/10/DJM.T/2016. The results of the sequential performance test for B10, B15, B20 produce peak power at 2000 RPM with values of 38.74 Hp, 40.35 Hp, 39.14 Hp, peak torque at 1800 RPM of 146.56 Nm, 153.37 Nm, 150.94 Nm, sfc 0.20 kg/Hp.h, 0.21 kg/Hp.h, 0.21 kg/Hp.h, and thermal efficiency 32.60%, 29.91%, 30.87%.*

Kata Kunci: *biodiesel; spent coffee grounds; transesterification; methyl esters; performance test.*

1 Introduction

Energy demand has continued to rise since the industrial revolution and continues to increase as industry develops and population growth. About 80% of the world's energy is supplied by fossil fuels, which will be exhausted by the years to come. Pressure to replace fossil fuels exists[9]. This is because the price of fossil fuels is rapidly rising and fluctuating and there is an increasing awareness of the negative impacts of fossil resources[1]. Biodiesel is an alternative for fossil fuel. In recent years, biodiesel production has received attention because of its easy portability[6]. Biodiesel fuel is non-toxic, biodegradable, and is obtained through transesterification of triglycerides with short chain alcohols. Biodiesel has a higher cetane number than diesel fuel, does not contain aromatic and no sulfur. Furthermore, biodiesel has fewer CO, CO2, and hydrocarbon emissions[1]. However, biodiesel is more expensive than fossil fuels. The production cost of biodiesel comes from raw materials, around 70-95% of the total cost[6]. In 2007, the price of vegetable oil per month more than doubled in the early 2000s. The limited availability of vegetable oils and the demand for vegetable oils is an important issue in the production of cost-effective biodiesel[1]. To solve this problem, the industries use waste vegetable oils and animal fats to produce biodiesel[6]. Some also use non-edible waste as a biodiesel producer[5].

Coffee is one of the largest agricultural products used for beverages and consumed throughout the world. According to the U.S. Department of Agriculture, the world’s coffee production is 16.34 billion pounds per year[6]. Brazil, Vietnam, Indonesia and Colombia are the main producing countries for coffee [9]. For Indonesia, coffee production in 2016 according to the Central Bureau of Statistics is 610.42 thousand tons. East Java contributed 33.98 thousand tons[11].The production of coffee beverages produce a number of spent coffee grounds which cause problems with waste disposal. Spent coffee grounds are problematic due to the high oxygen demand during decomposition and potential release of residual contaminants to the environment. Valorization of spent coffee grounds is an alternative to reclaim energy and produce biodiesel. Spent coffee grounds are attractive for biodiesel production due to their high lipid content, which is 10-15% by dry weight[12]. The yield and quality of biodiesel depends on the spent coffee grounds itself (quality, moisture, particle size), oil extraction methods (soxhlet extraction, supercritical fluid extraction, ultrasonic extraction, micro extraction), extraction conditions (solvent type, solvent amount, technological extraction, extraction time) and biodiesel production method[3]. Moreover, spent coffee grounds oil has a high antioxidant content. This keeps the oil stable (ie, the oil does not rot very quickly). Low levels of saponification make the oil remain thick and not easily clogged. Therefore, the spent coffee grounds oil is potential for use in biodiesel[1]. Biodiesel production from spent coffee grounds oil involves collecting and transporting coffee residues, drying, oil extraction using soxhlet extraction method and biodiesel production after transesterification to produce fatty acid methyl esters[3]. In London, a company called Bio-Bean has used spent coffee grounds as fuel for several London city buses. Bio-Bean collects spent coffee grounds from all over the UK, and then turn the spent coffee grounds into biodiesel fuel at the plant located in Cambridgeshire. The existing biodiesel is B20[4].

2 Research Methods

In this research, the first thing to do is prepare spent coffee grounds and dried in the sun for 5 days.The next step is to prepare tools and materials, i.e., digital scales, measuring cup, funnels, soxhlet sets, electric stoves, pots, hoses, buckets, water pumps, filter paper, dried spent coffee grounds and N-Hexane. The extracting is done with soxhlet which takes 1-1.5 hours, requires 50 gram dried spent coffee grounds, 150 ml N-Hexane. After the soxhlet extraction process, do the process of purifying the spent coffee grounds oil using rotary evaporator. The rotary evaporator process requires a temperature of 60°C and a time of 30-45 minutes. After this process is complete, obtained spent coffee grounds oil which is separate from N-Hexane.

After that, the transesterification process is carried out. Tools and materials needed are magnetic hotplate stirrer, thermometer, measuring cup, scales, stirrer rod, methanol, NaOH, and spent coffee grounds. The transesterification process uses NaOH as much as 1% of the oil mass and methanol 40% of the oil volume. The first step is to dissolve NaOH and methanol, followed by mixing the solution with spent coffee grounds oil using a magnetic hotplate stirrer at 70^{o}C and stirring 600 rpm for 1.5-2 hours. After the transesterification process is complete, let stand for 24 hours so the methyl esters and glycerol separate.

Mixing with diesel fuel is done by percentage of methyl ester volume of 10%, 15%, and 20%. Then testing the characteristics at the UPPS Laboratory of Pertamina Surabaya. The samples tested were diesel fuel, Pertamina's biodiesel, B10, B15, B20, and B100. Parameters are higher heating value, density, kinematic viscosity, flash point, and pour point.

Performance testing was carried out on diesel fuel, Pertamina's biodiesel, B10, B15 and B20 samples at the Motor Bakar Laboratory of Petra Christian University Surabaya. Testing is done by using a water brake dynamometer to determine the power, torque, specific fuel consumption, thermal efficiency with the braking method changed.

3 Result and Discussion

3.1 Characteristic Test Results

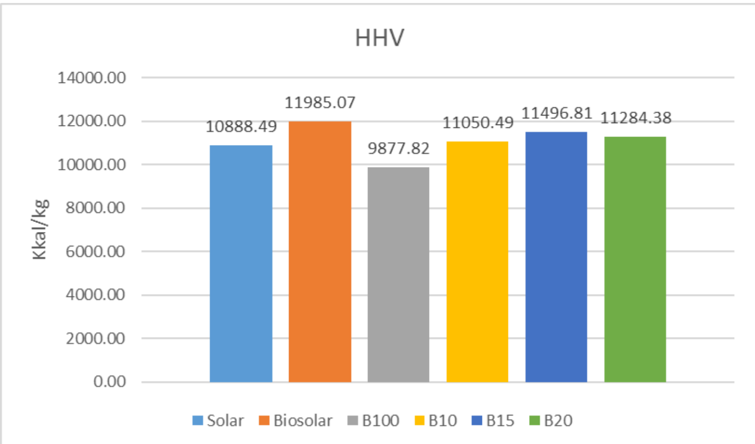
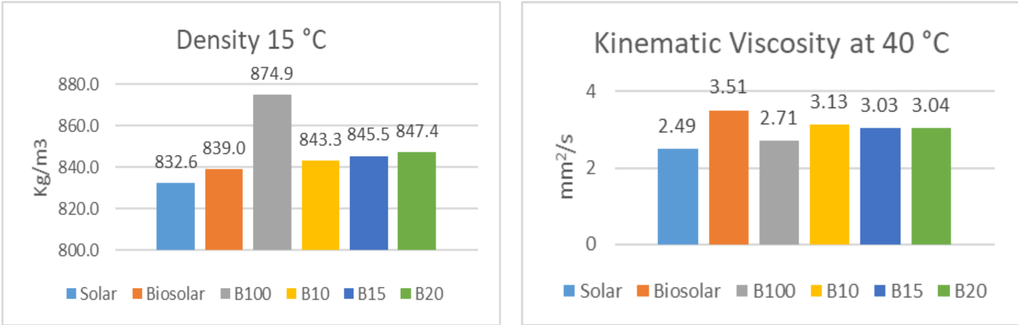


Figure 1. Graph of Comparison of Higher Heating Value

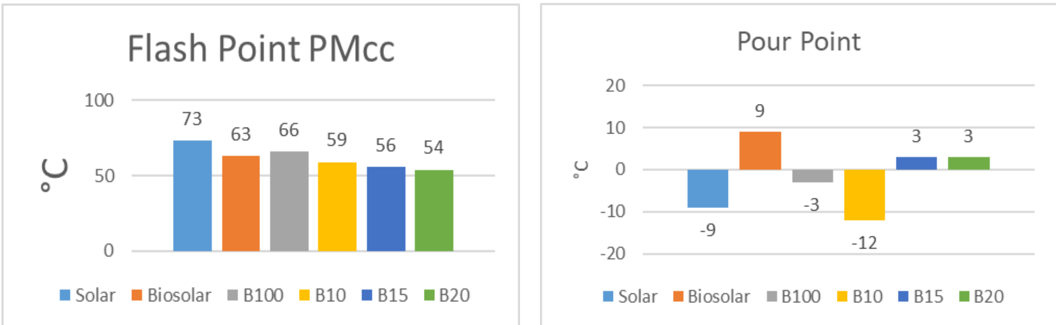
From Figure 1. it can be seen that the highest heating value is in Pertamina's biodiesel with 11985.07 Kkal/kg. And B100 diesel fuel blending with percentage of blend B15 has the highest value among other blend with 11496.81 Kkal/kg, followed by B20 with 11284.38 Kkal/kg and B10 with 11050.49 Kkal/kg. B100 diesel fuel blending can increase the heating value due to lower oxygen content. The increasing heating value will affect fuel consumption, torque and the ability to continue the power (deliverability). The loss caused by high heating values is the high carbon residue in the combustion engine room[10].



(a) (b)

Figure 2. Graph of Comparison of (a) Density at 15 °C, (b) Kinematic Viscosity at 40 ºC

When seen in Figure 2. (a) the percentage of B100 diesel fuel blending causes an increase in the density value, i.e., 843.3 kg/m^3 for B10, 845.5 kg/m^3 for B15, and 847.4 kg/m^3 for B20. The higher the density value will adversely affect the performance of the injectors due to the greater loading and filling of the fuel atomization efficiency for the combustion system[10]. While from Figure 2. (b) it can be seen that the highest kinematic viscosity value is in Pertamina's biodiesel with 3.51 mm^2/s. This is followed by B10, B20, B15 which has 3.13 mm^2/s, 3.04 mm^2/s, and 3.03 mm^2/s. Increased kinematic viscosity value due to cyclopropene fatty acid and high palmitic acid[2]. The higher the kinematic viscosity value leads to a larger droplet size resulting in injector resistance and forming the engine deposit due to inadequate fuel atomization. And usually the higher the kinematic viscosity value the lower flash point value[10].



(a) (b)

Figure 3. Graph of Comparison of (a) Flash Point, (b) Pour Point

If seen in Figure 3. (a) the percentage of B100 diesel fuel blending causes the decrease of flash point value, i.e., B20 with 54^{O}C, B15 with 56^{O}C, and B20 with 59^{O}C. The lower the flash point value accelerates the speed of burning of the fuel[7]. In addition, fuel storage should be at a temperature lower than the flash point value in order to avoid an explosion because the temperature exceeds the flash point value[10]. While from Figure 3. (b) it can be seen that the lowest pour point value is in B10 with -12^{O}C and the highest pour point value is in Pertamina's biodiesel with 9^{O}C. Pour point is the temperature when the liquid starts to gel (or no longer viscous) so it can be known the quality of fuel at low temperatures. The lower pour point value, the fuel is not easy to freeze and does not cause difficulties at the cold starting engine conditions or in the morning[8]. The low pour point is due to the high unsaturated fatty acids[2].

3.2 Performance Test Results

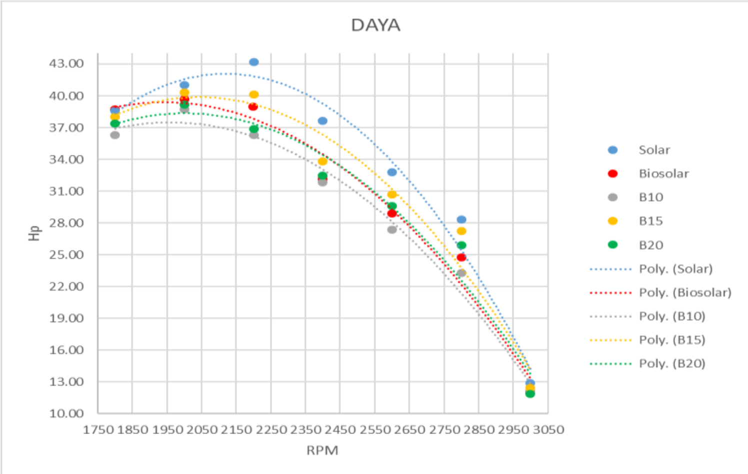


Figure 4. Graph of Comparison of Power

In Figure 4. shows that at 2200 RPM is the peak point of power of diesel fuel with 43.2 Hp and at 2000 RPM is the peak point of power of Pertamina's biodiesel, B10, B15, and B20 with 39.68 Hp, 38.74 Hp, 40.88 Hp, and 38.74 Hp. Although not at its peak, diesel fuel at 2000 RPM still has more power than Pertamina's biodiesel, B10, B15, and B20 with 41.02 Hp. So that it can be sorted at 2000 RPM from the biggest power, namely diesel fuel, B15, Pertamina's biodiesel, B20, and B10. If ppeak point of power is B10, B15, B20 compared to Pertamina's biodiesel, there is an increase 1.69% for B15 and a decrease 2.36%, 1.35% for B10 and B20. Based on the analysis of the heating value test, the power increases if the heating value is high but here the lowest heating value (diesel fuel) has the greatest power that may be caused by its physical properties, namely density, viscosity and sulfur content which is indeed lower than other fuels

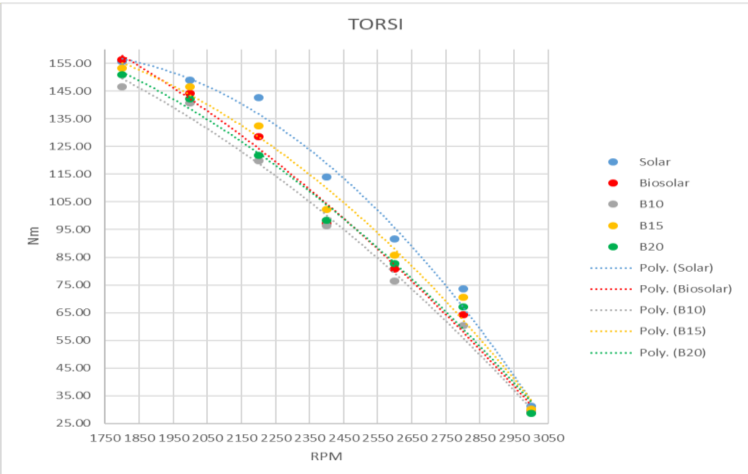


Figure 5. Graph of Comparison of Torque

In Figure 5. shows that at 1800 RPM is the peak point of torque of diesel fuel, Pertamina's biodiesel, B10, B15, and B20 with respective values of 155.81 Nm, 156.29 Nm, 146.56 Nm, 151.91 Nm, and 152.40 Nm and the highest torque is in Pertamina's biodiesel. But if you pay attention again, the highest torque at 2000 RPM and above is on diesel fuel, followed by B15. So if it is sorted at 1800 RPM from the biggest torque, namely Pertamina's biodiesel, diesel fuel, B15, B20, and B10. If the peak point of torque of B10, B15, B20 is compared with Pertamina's biodiesel there is a decrease 6.23%, 1.87%, 3.43% for B10, B15, and B20. Based on the analysis of the heating value test, torque also increases if the heating value is high but here, only the Pertamina's biodiesel corresponding to the analysis. It is possible because the cetane index is higher than others even though the viscosity is also higher.

Figure 6. Graph of Comparison of SFC

In Figure 6. shows that the peak point of SFC is at 3000 RPM for each fuel with Pertamina's biodiesel fuel being the highest value 0.51 kg/Hp.h. And the lowest SFC is at 1800 RPM for every fuel with Pertamina's biodiesel fuel again being the lowest value 0.17 kg/Hp.h. If it is sorted based on its peak power, that is at 2000 RPM from the smallest SFC, namely diesel fuel, B15, B10, B20, and Pertamina's biodiesel. However based on the analysis of the heating value test, the SFC will be high if the heating value is low because it is needed to compensate for the loss of heating value.This may be caused by high distillation temperatures so that less fuel can evaporate properly and cause less optimal combustion and increased fuel consumption. And the comparison for B10, B15, B20 with Pertamina's biodiesel at 2000 RPM will be found a decrease 5.16% for B10 and an increase 3.45% and 0.34% for B15 and B20.

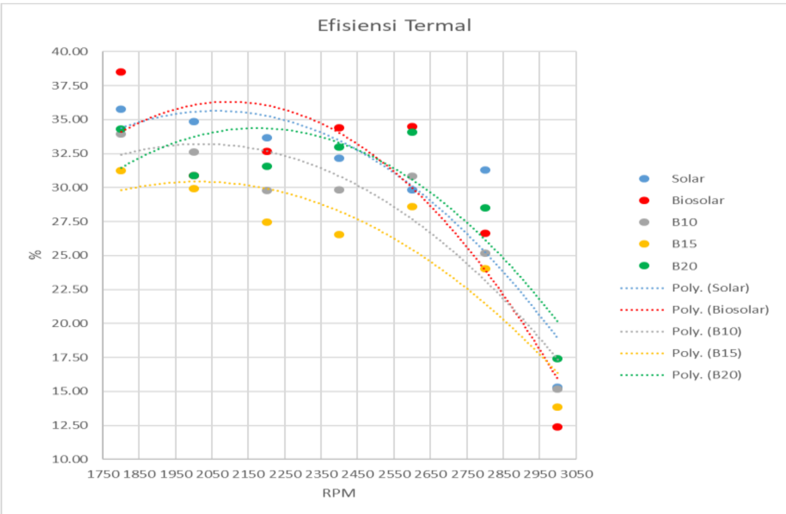


Figure 7. Graph of Comparison of Thermal Efficiency

In Figure 7. shows that at 1800 RPM is the peak point of thermal efficiency of diesel fuel, Pertamina's biodiesel, B10, and B20 sequentially 35.76%, 38.52%, 33.95%, and 34.63% and at 2000 RPM is the peak point of thermal efficiency of B15 31.06%.The lowest thermal efficiency is at 3000 RPM for each fuel with Pertamina's biodiesel fuel being the lowest value 12.41%. If it is sorted based on its peak power at 2000 RPM from the biggest thermal efficiency, namely diesel fuel, B10, B20, Pertamina's biodiesel, and B15. And the comparison for B10, B15, B20 with Pertamina's biodiesel at 2000 RPM will be found an increase 5.64% and 0.03% for B10 and B20 and a decrease 3.06% for B15.

4 Conclusion

From the research and testing that has been done, it can be concluded as follows:

1. Spent coffee grounds can be used as an alternative energy source to biodiesel.
2. B10, B15, and B20 may be used as a substitute for diesel fuel or Pertamina's biodiesel because it meets the requirements of the Directorate General of Oil and Gas Indonesia.
3. B10, B15, and B20 have higher density values than diesel fuel dan Pertamina's biodiesel, i.e., sequentially 843.3 kg/m^3, 845.5 kg/m^3, and 847.4 kg/m^3.
4. B10, B15, and B20 have lower kinematic viscosity than Pertamina's biodiesel, i.e., sequentially 3.13 mm^2/S, 3.03 mm^2/S, and 3.14 mm^2/S but still higher than diesel fuel.
5. B10 differs from Pertamina's biodiesel by -2.36% Hp, -6.23% Nm torque, -5.16% kg/Hp.h SFC, and 5.64% thermal efficiency so generally this mixture produces a much lower performance.
6. B15 differs from Pertamina's biodiesel by 1.69% Hp, -1.87% Nm torque, 3.45% kg/Hp.h SFC, and -3.06% thermal efficiency so generally this mixture produces performance which is slightly higher.
7. B20 differs from Pertamina's biodiesel by -1.35% Hp, -3.43% Nm torque, 0.34% kg/Hp.h SFC, and 0.03% thermal efficiency so generally this mixture produces performance the lower one.

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