

Durability of Diesel Engine Using Biolubricant and the Effect on Performance

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Abstract— environmental needs to reduce pollution caused by used lubricants from mineral oil encourage the development of biolubricant. One of the biolubricant raw materials from plants available in the environment is the castor plant (*ricinus communis*). The biggest composition in castor oil is ricinoleic acid which can be used in the manufacture of biolubricants. The purpose of this study was to study the physical properties of biolubricants from castor oil, to compare the properties of biolubricants and mineral lubricants after conducting a diesel engines durability test, and comparing performance between both lubricants during durability test. Experiment were carried out on the Dongfeng R180 diesel engine using Pertamina Dexlite fuel and mineral oil Pertamina Mesran B SAE 40 as a comparison. The results of biolubricant properties test (kinematic viscosity, viscosity index, pour point, flash point, and total alkali number) were obtained according to the flash point value not fulfilling the Minister of Energy and Mineral Resources Regulation regarding standard. From properties between biolubricants and mineral lubricants after a 200-hour endurance test there is properties change in both lubricants. Increase the value of viscosity, total number of base, and flash point because it contains water in the biolubricant causing oxidation. The iron content of the biolubricants after the endurance test is greater than mineral lubricants. However, the aluminum content in biolubricants is smaller when compared to biolubricants. From the performance test obtained SFOC which is produced when using mineral oil at peak torque is 3.1% lower than compared when using biolubricants. The average SFOC in the value condition when using biolubricants is 2.3% lower than using biolubricants. The average power when using mineral lubricants is 0.72% lower when compared to biolubricants and the resulting torque is 0.23% lower when compared to using biolubricants.

Keywords— Biolubricant. engine performance, lubricant properties, metal content.

I. INTRODUCTION

The lubricant oil used in an engine act as a lubricant, a coolant, and a impurities remover. It must be able to resist high temperatures without destroying components and have a long lifespan. Lubricant oils used in modern engines must be able to operate in a wide temperature range. They must lubricate properly from a chilly engine's starting temperature to the severe steady-state temperatures found within the cylinders. They can't oxidize on the combustion chamber walls or other hot locations like the piston's center crown or top piston ring [1].

Plant oils differ from mineral oils in that they have a different chemical structure. Plant oils have a higher viscosity index and are better at lubricating. Vegetable oils have better anticorrosion characteristics, which are caused by a higher affinity for metal surfaces. Vegetable oils with flash points more than 300°C are classified as non-flammable liquids. Vegetable oils, on the other hand, have a limited application in lubrication due to their low oxidative stability and higher melting temperatures [2]. Biolubricants derived from renewable sources have long been known for their numerous

advantages. Biolubricants, in general, have very low or minimal aquatic toxicity and are rapidly biodegradable in most circumstances [2].

Castor oil's superior tribological performance to foreign high quality crankcase oil demonstrates that, if other properties of the oil are improved to meet the requirements for internal combustion engines, it can be a better lubricating oil than the mineral oil-based crankcase oils currently on the market [3].

II. METHOD

To resolve the research conducted is by experiment. First of all to conduct the experiment is know the properties of castor oil biolubricant. After that is test the biolubricant on durability test in diesel engine and during the experiment fuel consumption is observed. Finally, the goal of this research is analysis the properties and metal content used lube oil after experiment.

A. Production of Biolubricant

Production of biolubricant using 4 process which is esterification, transesterification, epoxidation, and epoxide ring opening reaction process based on the reference. In this process also conduct equipment and material preparation in order to produce biolubricant. This test is conducted to know the succes level of the production process.

This test also will show the information whether this type of biolubricant meet Ministry of Energy and Mineral Resources requirement or not. The biolubricant properties that will be tested are : kinematic viscosity at 40°C and 100°C, flash point, pour point, viscosity index and total base number.

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B. Engine Set Up

Engine setup is a process of arranging the system configuration for the experiment. The engine setup will be shown in figure 1.

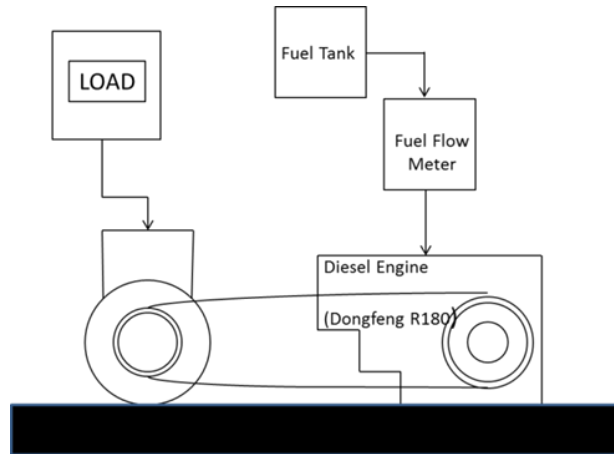


Figure. 1. Engine Setup.

New DongFeng R180 diesel engine (one cylinder, four stroke, natural aspirated) were used as test engine. The DongFeng engine specification is listed in table 1.

TABLE 1.
DONGFENG R180 ENGINE SPECIFICATION

Specification Type	Dimension Inline, Four Stroke
No. of Cylinder	1
Bore	80 mm
Stroke	80 mm
Displacement	402 cc
Oil Capacity	2.5 Liters

C. Test Procedure

Test procedure use Engine Manufacturing Association 200-h standard. The purpose of this test was to assess the impact of using biolubricant on fuel consumption and biolubricant properties changes.

The four load engine cycles are described as follows :

1. 1. Rated speed: A load was applied at full throttle until the engine speed dropped to the manufacturer's specified rated speed.
2. 2. Peak Torque: A load was given to the engine at full throttle until the engine speed dropped to the manufacturer's rated torque speed (1900 rpm).
3. High Idle: The load was placed at 25% of maximum torque, and the throttle was modified to get the engine to run at 90% of rated speed (1980 rpm, 850 W dummy load).
4. No load: The throttle was changed at no load in

order to obtain the manufacturer's specified curb idling (850 rpm).

D. Oil Analysis

The contaminant content of lubrication oil has been found to be an effective indicator of engine problems. Excess metal contamination in the lubrication oil indicates wear difficulties, and changes in characteristics can indicate the status of the component. For this test, lubrication oil will analyze after 200-hours experiment.

III. RESULTS AND DISCUSSION

A. Properties of Castor Oil Biolubricant

In the process of making biolubricant, it generally have a standard of biolubricant quality which that is kinematic viscosity at temperature 40°C and 100°C, flash point, pour point, viscosity index, and total base number.

TABLE 2.
PROPERTIES OF CASTOR OIL BIOLUBRICANT

Parameter	Result	Unit	Test Method
Viscosity 40°C	98.69	mm ² /s	ASTM D445
Viscosity 100°C	9.674	mm ² /s	ASTM D445

Viscosity Index	68	-	ASTM D2270
Flash Point	131	°C	ASTM D92
Pour Point	-15	°C	ASTM D97
Total Base Number	9.76	mg/g	ASTM D2896

TABLE 3.
 PROPERTIES BOTH LUBRICANT AFTER EXPERIMENT

Parameter	New Pertamina Mesran B SAE 40 Lubricant	Used Pertamina Mesran B SAE 40 Lubricant	New Castor Oil Biolubricant	Used Castor Oil Biolubricant	Units
Viscosity 40°C	145.80	80	98.69	253.7	mm ² /s
Viscosity 100°C	14.9	14	9.674	21.10	mm ² /s
Viscosity Index	102	99	68	98	-
Flash Point	230	<230	131	202	°C
Pour Point	-12	-3	-15	-3	°C
Total Base Number	11.70	11.38	9.76	11.35	mg/g

B. Lubricant Analysis

After EMA’s durability experiment using castor oil biolubricant and Pertamina Mesran B SAE 40 lube oil, there must be changing in their quality for lubricant the component. This is because the basic ingredients and the production process of Pertamina Mesran B SAE 40 lubricant oil come from mineral oil residues. While the

castor oil biolubricant comes from vegetable ingredients so it has a different treatment. When tested on a diesel engine, lubricants changes in chemical physics. The summary of comparison result between using both of them can see in table 3.

- Kinematic Viscosity at 40°C and 100°

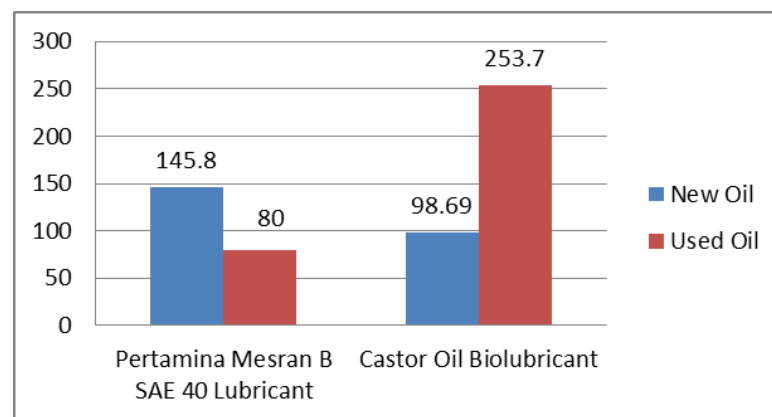


Figure. 2. Kinematic Viscosity at 40°C.

Based on figure 2, the initial conditions, Pertamina Mesran B SAE 40 lubricant has a viscosity of 145.8 cSt. After experiment the viscosity decrease into 80 cSt. Different condition on biolubricant after experiment,

when viscosity at 40 ° C increase 30% from initial condition.

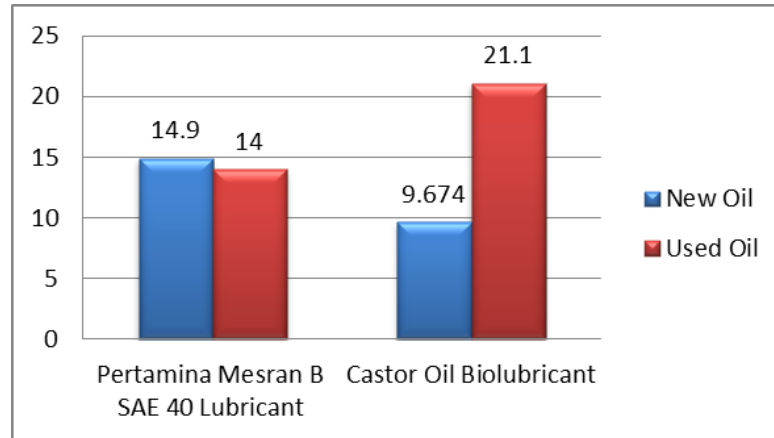


Figure 3. Kinematic Viscosity at 100°C.

The same conditions occur on kinematic viscosity at 100°C when biolubricant and Pertamina lubricant have different changes. Reduced viscosity due to fuel dilution, moisture addition, and shearing of viscosity index improver additives [3]. Fuel dilution occur because of

the wear on piston ring that increase a gap between cylinder liner and piston ring.

The increased viscosity on biolubricant due to oil's base-stock oxidation, evaporation of lighter fractions, depletion of anti-wear additives, and contamination by insoluble [4].



(a)



(b)

Figure 4. Connecting Rod using (a) Castor Oil Biolubricant (b) Pertamina Mesran B SAE 40.

Initial conditions of biolubricant has 11% water content influence of viscosity increase and the effect if there is water on lubricant is oxidation. Oxidation can cause the lubricant to become thick and form a sludge that can adhere to the engine components.

Figure 5 presented two different condition between using different lubricant. It shows the effect on oxidation in biolubricant on valve is deposit arises in valve.



(a)



(b)

Figure 5. Valve using (a) Castor Oil Biolubricant (b) Pertamina Mesran B SAE 40 Lubricant.

- Viscosity Index

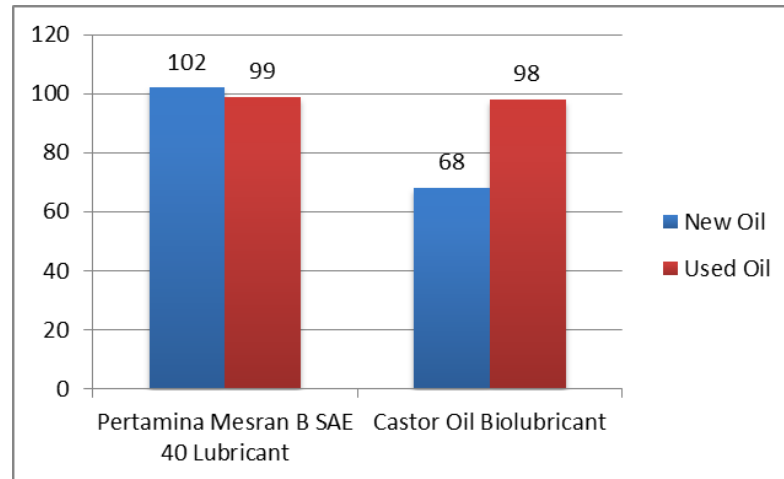


Figure. 6. Viscosity Index.

The determination of the viscosity index value is obtained by looking for the viscosity value at 40 ° C and 100 ° C and the calculation procedure is in ASTM D2270. The viscosity index on two lubricants changes differently. In Pertamina Mesran B SAE 40 lubricant, viscosity index experienced a 2.95% decrease which is directly proportional to the decrease in kinematic viscosity value of the lubricant. A decrease in the viscosity index value can cause several effects such as excessive wear and increase friction between

components. A decrease in the value of the viscosity index can also be caused by the occurrence of fuel dilution [5].

Meanwhile, for castor oil biolubricant, it has increased by 44% compared to the initial condition of the biolubricant. This increase together with the thickening of the lubricant caused by oxidation.

- Flash Point

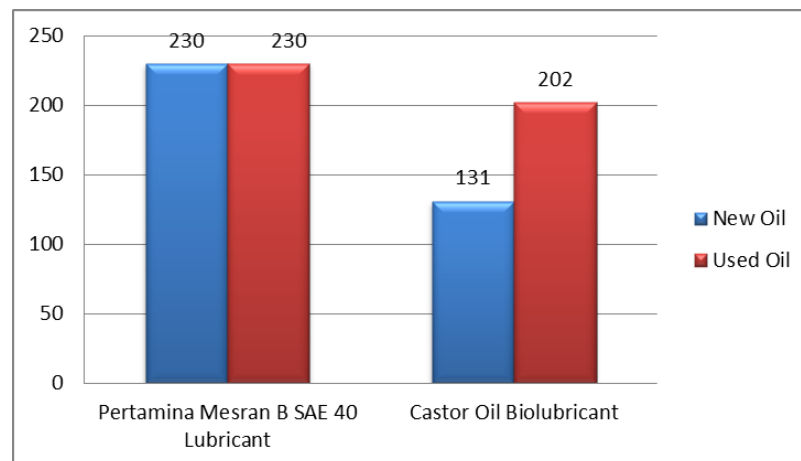


Figure. 7. Flash Point.

Variation of flash point of lubricating oil when using biolubricant and mineral lubricant is presented on figure 4. Flash point value on both lubricant was increase after experiment. The increase in flash point by 52.4% occurred in biolubricant oil. The more water content in oil, the higher the flash point value [6]. The water content in Pertamina mesran B SAE 40 lubricants after experiment was 3.738%. The same thing also occur in biolubricant, although water content in lubricant decrease significantly, but the lubricant have already the effect of oxidation.

- Total Base Number

Different result of total base number (TBN) for both lubricant are presented on figure 6. Initial TBN value owned by Pertamina Mesran B SAE 40 lubricant is 11.70 mg/g. The condition different after experiment where TBN value decrease 2.7% into 11.38 mg/g. The TBN reduction is still within reasonable limit. Lubricant still can be used from TBN value because the reduction not until 50% [7].

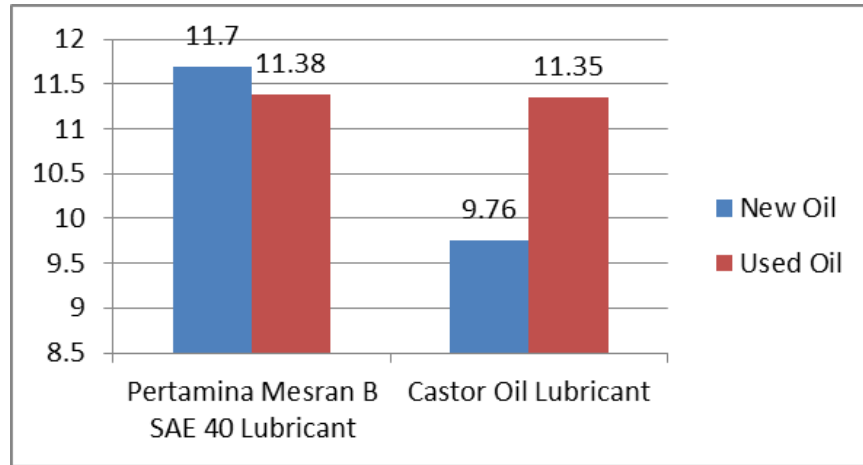


Figure 8. Total Base Number.

Material Safety Data Sheet issued by Pertamina for Pertamina Mesran B SAE 40 Lubricant states that the lubricant will be stable when at temperatures below 85°C and when the lubricant temperature is above 85°C the lubricant will emit Hydrogen Sulfide (H₂S) which can cause strong acids in combustion chamber so that it can reduce the TBN value of the lubricant.

In castor oil biolubricant total base number (TBN) value is increase. Increase value of TBN in the process starts from the heat that occurs on the engine. This heat produces conditions that make it easy for the occurrence of volatility. Biolubricant initially contain a lot of water

content so the water easily evaporate at high temperatures. This case makes the increase of TBN.

C. Metal Contaminant Analysis

Engine wear was evaluated on the basis of the concentration of wear metals in the lubricating oil. The metals considered were iron (Fe), chromium (Cr), aluminum (Al). The primary sources of these wear metals, respectively, have been identified as cylinder wear, ring wear, bearing wear, piston wear, all engine moving parts made out of cast iron, and any part containing ceramics [8].

TABLE 4. METAL CONTAMINANT ON LUBRICANT

Parameter	Castor Oil Used Oil	Pertamina Mesran B SAE 40 Used Oil	Unit	Test Method
Iron (Fe)	19	1.34	ppm	AAS-Flammable
Alumunium (Al)	2.52	6.26	ppm	AAS-Flammable
Chromium	<0.006	<0.006	ppm	AAS-Flammable

- Iron (Fe)

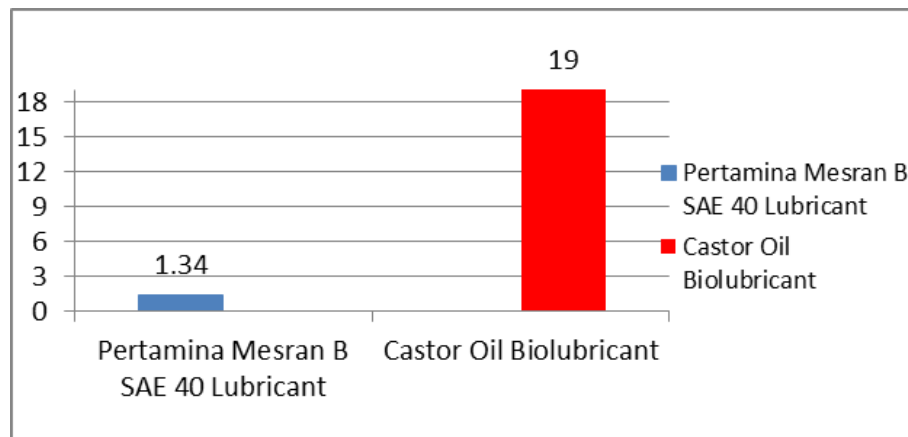


Figure 9. Iron Content on Lubricant.

Figure 9 shows wear metal concentration in part per millions. Pertamina mesran B SAE 40 has iron content of 1.34 ppm which less than 19 ppm biolubricant iron content.

The comparison iron content between can be indicated on component effect on figure 10.



Figure 10. Journal Bearing using (a) Pertamina Mesran B SAE 40 lubricant (b) Castor Oil Biolubricant.

The journal bearing used in the experiment using cast iron as raw material. An indication of the occurrence of scratches is due to the oxidation process that causes

excessive wear in the journal bearing when using biolubricant.

- Aluminium (Al)

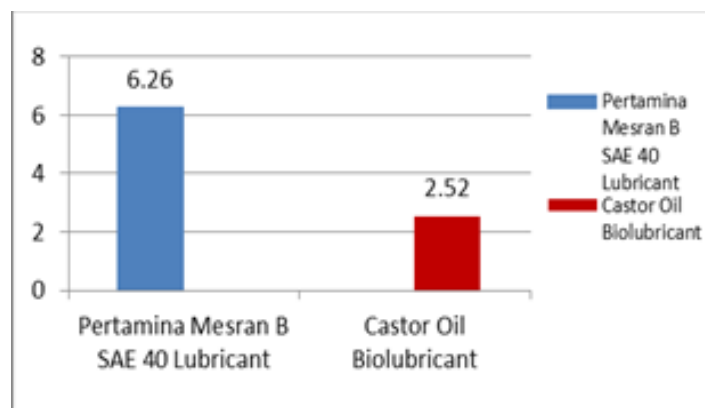


Figure 11. Aluminium Content on Lubricant.

Aluminium is one of the material in diesel engine. The 200-hour diesel engine endurance experiment shows that the aluminum content in the biolubricant has a value of 2.53 ppm, less when compared to mineral lubricants

which have an aluminum content of 6.26 ppm. Aluminum metal material contained in lubricating oil can be caused by wear on the piston.

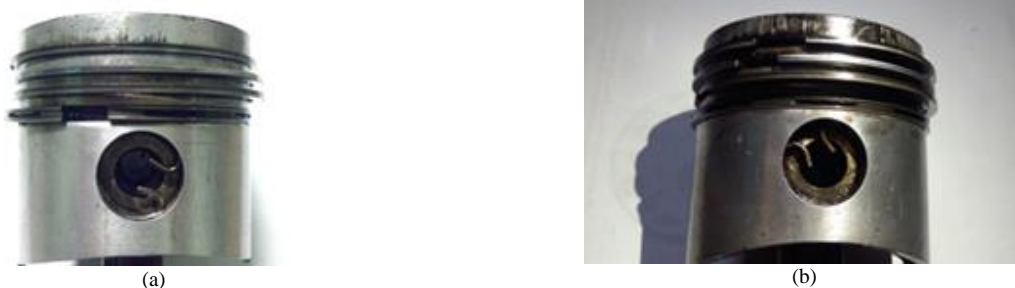


Figure 12. Piston Crown using (a) Pertamina Mesran B SAE 40 Lubricant (b) Castor Oil Biolubricant.

Visually both piston with different lubricant have a scratches. The scratches come from the friction between the piston and the cylinder liner. In addition, on biolubricant an indication of the poor lubrication effect due to oxidation in the biolubricant also results in wear on the piston.

- Chromium (Cr)

Figure 13 shows the chromium content. The content of chromium found in engine components after the 200 hour test shows very little results in both lubricants. In castor oil biolubricants and pertamina mesran B SAE 40 lubricants chromium content is <0.006 ppm

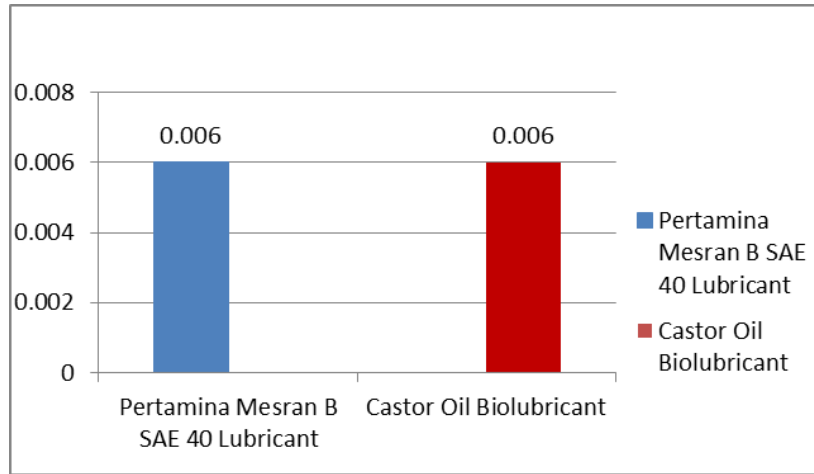


Figure 13. Chromium content on Lubricant.

D. Engine Performance

Before the 200- h engine endurance experiment was carried out with a method that refers to EMA (Engine Manufacturing Association) and to see engine performance performed engine mapping to determine engine speed and load in low idle conditions, idle high, rated speed, and peak torque . In this experiment there are two types of lubricants that will be compared, Castor Oil Biolubricant and Pertamina Mesran B SAE 40 Lubricant. The type of fuel used is using Pertamina Dexlite.

During durability test using Engine Manufacturing Association (EMA) 200-h standard, the fuel consumption was observed. The trends specific fuel oil consumption (SFOC) on rated speed and peak torque condition during experiment are shown in figure 14 and figure 15.

- Specific Fuel Oil Consumption (SFOC) Rated Speed

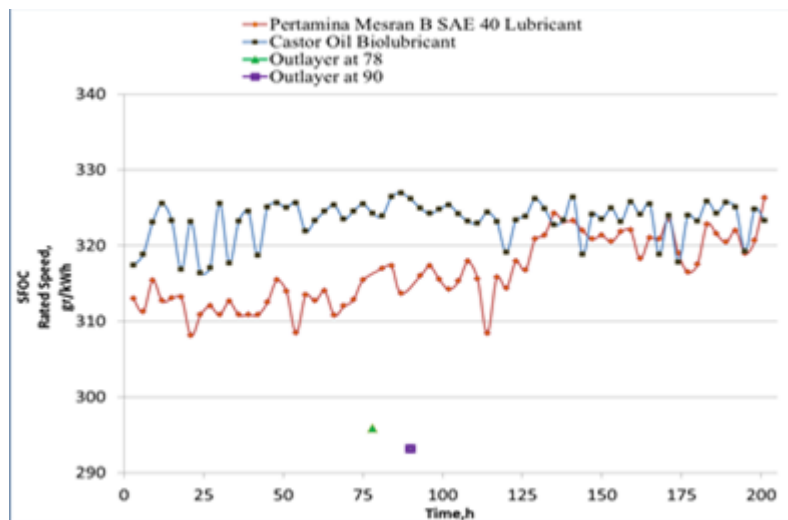


Figure 14. SFOC at Rated Speed.

The factor that affect fuel consumption on engine besides the type of fuel used is type of the lubricant used. Bad lubricants can increase the friction that arises between components resulting in heavier work on the engine components. The fuel consumption when using Pertamina Mesran B SAE 40 is less than when compared with castor oil biolubricant. Pertamina Mesran B SAE B 40 lubricant is more stable in lubricating and does not cause excessive friction on the components in the combustion chamber is the factor the fuel consumption less than using biolubricants.

SFOC when engine run at rated speed is in the range 310-320 gr / kWh. The average SFOC result by using castor oil biolubricant is 323 gr/kWh. It indicate that fuel consumption when using castor oil biolubricant is greater than pertamina mesran B SAE 40 lubricants. Mechanism failure occur on experiment at hour 78 and 90 raises SFOC go down at makes an out layer on graphic.

- Specific Fuel Oil Consumption (SFOC) Peak Torque

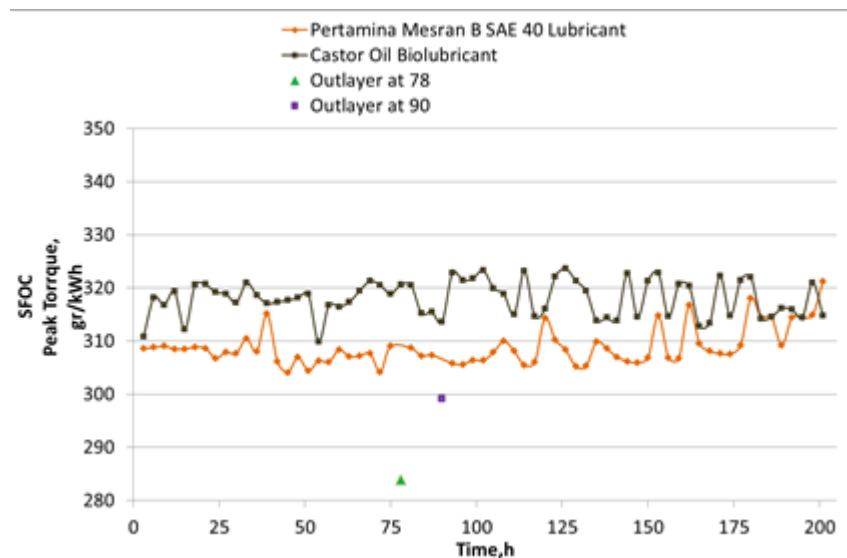


Figure. 15. SFOC at Peak Torque.

On the figure 14 are presented SFOC at peak torque condition during 200-h experiment. At peak torque condition the trend shows that SFOC when engine using biolubricant is greater than using Pertamina lubricant. It can shows from the average SFOC when use biolubricant is 318.05 gr/kWh, beside that SFOC while engine use Pertamina lubricant is on average 308 gr/kWh.

Higher fuel consumption is the effect on friction on combustion chamber. On figure 7 presented that iron content when using biolubricant is greater than Pertamina lubricant. A lot of iron content signify an excessive friction. Mechanism failure occur on experiment at hour 78 and 90 raises SFOC go down at makes an out layer on graphic

IV. CONCLUSION

In this study it can be concluded that the use of biolubricants in diesel engines has not been maximized due to oxidation and large amount of water content in the lubricant. Oxidation causes changes in viscosity to become thicker and lubrication to be not optimal due to the high iron content compared to Pertamina Mesran B SAE 40 lubricants. SFOC value when using biolubricants is greater than use Pertamina Mesran B SAE 40 lubricant in two conditions during the experiment. It indicates that the use of Pertamina lubricants is better in terms of lubricating the components and the consumption of fuel produced.

REFERENCES

- [1] W.Pulkrabek, W. (2004). Engineering Fundamentals of the Internal Combustion Engine (Second Edi., p. 478). Pearson Prentice-Hal
- [2] J. Salimon, N. Salih, and E. Yousif, "Biolubricants: Raw materials, chemical modifications and environmental benefits," *European Journal of Lipid Science and Technology*, p. NA-NA, 2010.
- [3] Bongfa, B., Atabor, P.A., Barnabas, A., Adeoti, M.O., 2015. Comparison of lubricant properties of castor oil and commercial engine oil 11.
- [4] A. Kumar Agarwal and A. Dhar, "Wear, durability, and lubricating oil performance of a straight vegetable oil (Karanja) blend fueled direct injection compression ignition engine," *Journal of Renewable and Sustainable Energy*, vol. 4, no. 6, p. 063138, Nov. 2012.
- [5] S. Yunus, A. A. Rashid, S. A. Latip, N. R. Abdullah, M. A. Ahmad, and A. H. Abdullah, "Comparative Study of Used and Unused Engine Oil (Perodua Genuine and Castrol Magnatec Oil) based on Property Analysis basis," *Procedia Engineering*, vol. 68, pp. 326–330, 2013.
- [6] Arunachaleswara PR, Rajesh Kanna, Sreeraj G Nair, Cifin Francis, Nisanth Bhaktan, Alvin Kuruvila, "Effect of Free Water and Rust on Flash Point on Diesel" *International Journal of Engineering and Science*, vol 7, pp 21-24, Feb 2017
- [7] M. Galbi, "Prediksi Penggantian Minyak Pelumas Motor Diesel Generator Set Berdasarkan Laju Perubahan Viskositas Dan Total Base Number Dengan Pendekatan Linieritas," vol. 12, p. 10, 2016.
- [8] Y. Ali and M. A. Hanna, "Durability Testing of a Diesel Fuel, Methyl Tallowate, and Ethanol Blend in a Cummins N14-410 Diesel Engine," *Transactions of the ASAE*, vol. 39, no. 3, pp. 793–797, 1996.