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COMPARISON OF BIODIESEL B-20 AND B-30 ON DIESEL ENGINE PERFORMANCES AND EMISSIONS

PERBANDINGAN BIODIESEL B-20 DAN B-30 PADA KINERJA MESIN DIESEL DAN EMISINYA

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ABSTRAK

Bahan bakar biodiesel merupakan energi terbarukan yang berasal dari sumber yang dapat diperbarui seperti minyak nabati (misalnya minyak sawit, minyak kedelai, dan minyak jarak) atau lemak hewan melalui proses trans-esterifikasi. Biodiesel dapat digunakan sebagai pengganti atau campuran bahan bakar minyak solar. Bahan bakar B-20 dan B-30 adalah campuran biodiesel dengan minyak solar yang masing-masing mengandung 20% biodiesel dan 80% minyak solar, serta 30% biodiesel dan 70% minyak solar. Tujuan dari penelitian ini adalah untuk membandingkan uji kinerja bahan bakar B-20 dan B-30 pada mesin diesel. Perbandingan yang dilakukan mencakup daya mesin, torsi mesin, konsumsi bahan bakar spesifik pada berbagai beban dan juga emisi. Dari hasil penelitian terlihat bahwa kinerja bahan bakar B-20 dan B-30 dipengaruhi oleh karakteristik fisika-kimia bahan bakar seperti viskositas kinematik, angka setana, berat jenis dan nilai kalor. Sementara itu dari uji kinerja diperoleh hasil bahwa bahan bakar B-30 mempunyai daya mesin yang lebih rendah 1,69% dan konsumsi bahan bakar spesifik lebih tinggi 0,62% daripada B-20 pada beban maksimum. Sedangkan emisi bahan bakar B-30 lebih baik dari B-20 karena terjadi penurunan opasitas asap rata-rata sebesar 6,71%.

Kata Kunci: *biodiesel, minyak solar, uji kinerja, daya mesin, konsumsi bahan bakar spesifik, emisi*

ABSTRACT

Biodiesel is renewable energy that is made from renewable sources such as vegetable oil (palm oil, soybean oil or jathropa oil) through a trans-esterification reaction. Biodiesel can be used as a substitute for diesel fuel or as a mixture with diesel fuel. B-20 and B-30 fuel are a biodiesel mixture with diesel fuel which contains 20% biodiesel and 80% diesel fuel and 30% biodiesel and 70% diesel fuel respectively. The aim of this study is to compare the performance tests of B-20 and B-30 on a diesel engine. Comparison of their performance comprises engine power, engine torque, specific fuel consumption (SFC) in various loads and emissions. Result shows that the B-20 and B-30 performance is affected by the chemical-physical characteristics of fuel, such as kinematic viscosity, cetane number, density and calorific values. Performance test results show that B-30 has 1.69% lower engine power and 0.62% higher SFC than B-20 at a full load condition. In contrast, B-30 has better emissions than B-20 with a 6.71% decrease in smoke opacity.

Keywords: biodiesel, diesel fuel, performance test, engine power, specific fuel consumption, emission

I. INTRODUCTION

Biodiesel, as an alternative fuel from diesel, is described as fatty acid methyl or ethyl esters derived from vegetable oils or animal fats. It is renewable, biodegradable and oxygenated (Xue, et al. 2011). Biodiesel fuel can effectively reduce engine-out emissions of particulate matter, carbon monoxide (CO), and unburned hydrocarbons in modern four-stroke compression–ignition engines. However, a slight increase in emissions of nitrogen oxides (NOx) has been observed in the use of oxygenated fuels in general. Another possible explanation for the increased NOx formation in biodiesel-fuelled engines has been attributed to the lower in-cylinder soot levels, thus lower radiation heat transfer resulting in higher in-cylinder temperatures. Nevertheless, low temperature combustion strategies, such as homogeneous charge compression–ignition enabling technologies and smokeless diesel combustion offer a promising solution to simultaneously reduce the formation of NOx and particulate matter (Lapuerta et al. 2008).

Although a considerable amount of research on biodiesel emphasizes that it might help to reduce greenhouse gas emissions, promote sustainable rural development, and improve income distribution, there still exists some resistance to using it. The primary cause is a lack of new knowledge about the influence of biodiesel on diesel engines. For example, the reduction of engine power for biodiesel, as well as the increase in fuel consumption, is not as much as anticipated. In addition, oxidation for biodiesel may result in insoluble gums and sediments that can plug a fuel filter, and thus it will affect engine durability (Xue et al. 2011). Biodiesel also has several properties that need to be improved, such as its lower calorific value, lower horsepower output, and its comparatively higher emission of nitrogen oxides (Buyukkaya, E. 2010).

Various factors are considered in using biodiesel as engine fuel, i.e. engine power, fuel efficiency, engine wear, deposits and clogging, pollution from engine exhaust and cold weather performance. Engine power and torque tend to be 3–5% lower when using biodiesel. This is due to the fact that biodiesel fuel has less energy per unit volume than traditional diesel fuel. Fuel efficiency tends to be slightly lower when using biodiesel due to the lower energy content of the fuel. Typically, the drop-off is in the same range as the reduction in peak engine power (3–5%). Short-term engine wear when using biodiesel has been measured to be less than that of petroleum diesel. Engines are expected to experience less wear in the long run when using biodiesel. Deposits and clogging due to biodiesel have been widely reported but are generally traceable to biodiesel that is either of a low quality or has become oxidized. If the fuel quality is high, deposits in the engine should not normally be a problem. Proper tuning of the engine can minimize this problem. Similar to petroleum diesel, engines tested in cold weather typically experience significant problems with operation caused primarily by clogging of the filters and/or choking of the injectors. The use of flow improving additives and "winter blends" of biodiesel and kerosene have proved effective at extending the range of operating temperatures for biodiesel fuel. Pure biodiesel tends to operate well at temperatures down to about 5 °C (this varies noticeably depending on the type of oil used). Additives typically reduce that range by about 5–8 degrees, while winter blends have proved effective at temperatures as low as −20°C and below (Dwivedy et al. 2011). However, engines tested in cold weather are not applicable in Indonesia.

Many studies into biodiesel based their research on vegetable oils derived from corn, cottonseed, peanut, soybean, rapeseed, and sunflower (Ma and Hanna, 1999). It is important to conduct research on biodiesel from palm oil, as Indonesia has abundant sources of palm oil. This alternative fuel is needed to reduce fuel imports into Indonesia.

The Ministry of Energy and Mineral Resources issued Regulation No. 12 Year 2015 on Supply, Utilization and Administration of Commerce Biofuels (Biofuel) as an alternative fuel. This regulation allows for biodiesel to be mixed with diesel fuel in order to reduce diesel fuel imports. The main objective of this study is to compare the engine performance and emissions of biodiesel B-20 and B-30. This is to support the regulation and also to provide technical recommendations to the government, since the regulation for B-30 will be implemented in January 2020.

II. METHODOLOGY

A. Preparation of Fuel and Physical-Chemical Characteristic Test

Diesel 48 and Biodiesel (B-100) were prepared to be blended. Before the blending process, a physical-chemical characteristics test should be done to make sure that both fuels were in accordance with the standard in Indonesia. Diesel 48 specification refers to the regulation issued by Directorate General of Oil and Gas of Government of Indonesia and the B-100 specification refers to the Indonesian National Standard (SNI 7182:2015). Afterwards, both fuels were blended into two different concentrations, i.e.: Biodiesel B-20, which was a mixture of 20% biodiesel and 80% Diesel Fuel 48, and Biodiesel B-30, which was a mixture of 30% biodiesel and 70%

Diesel Fuel 48. After finished the blending process, a physical-chemical characteristics test was conducted for those fuels.

B. Diesel Engine Performance Test on Static Multicylinder Test Bench

New engine spare parts were prepared before an overhaul of the Isuzu diesel engine test 4JA1. Afterwards, an overhaul of the diesel engine test was conducted by replacing old spare parts with the new spare parts prior to the performance test. The expectation was the engine would have optimal performance with new spare parts. A diesel engine performance test was carried out on a multicylinder test bench, high speed motor diesel, four stroke, four cylinder 2.499 cc, compression ratio 18.4:1, direct injection and naturally aspirated. Technical specifications of the test engine are shown in Table 1. The test was done in two cycles. The first cycle was for B-20 and the second cycle was for B-30. The parameters observed were power, torque, specific fuel consumption (SFC) and emission. An emission test was conducted based on the Indonesian National

Table 1
Technical specifications of the test engine

Parameters	Specifications
Manufacturers	Isuzu
Model	Four cylinder 4JA1
Cylinder diameter	93 x 92 mm
Volume	2499 cc
Compression ration	18,4 : 1
Maximum power	57,4/4000 (DIN 70020, ISO 1585)
Maximum torque	167/2300 (DIN 70020, ISO 1585)
Nozel Injector	Bosch four-hole type
Carburator	18,5 (185 kg/cm^2)

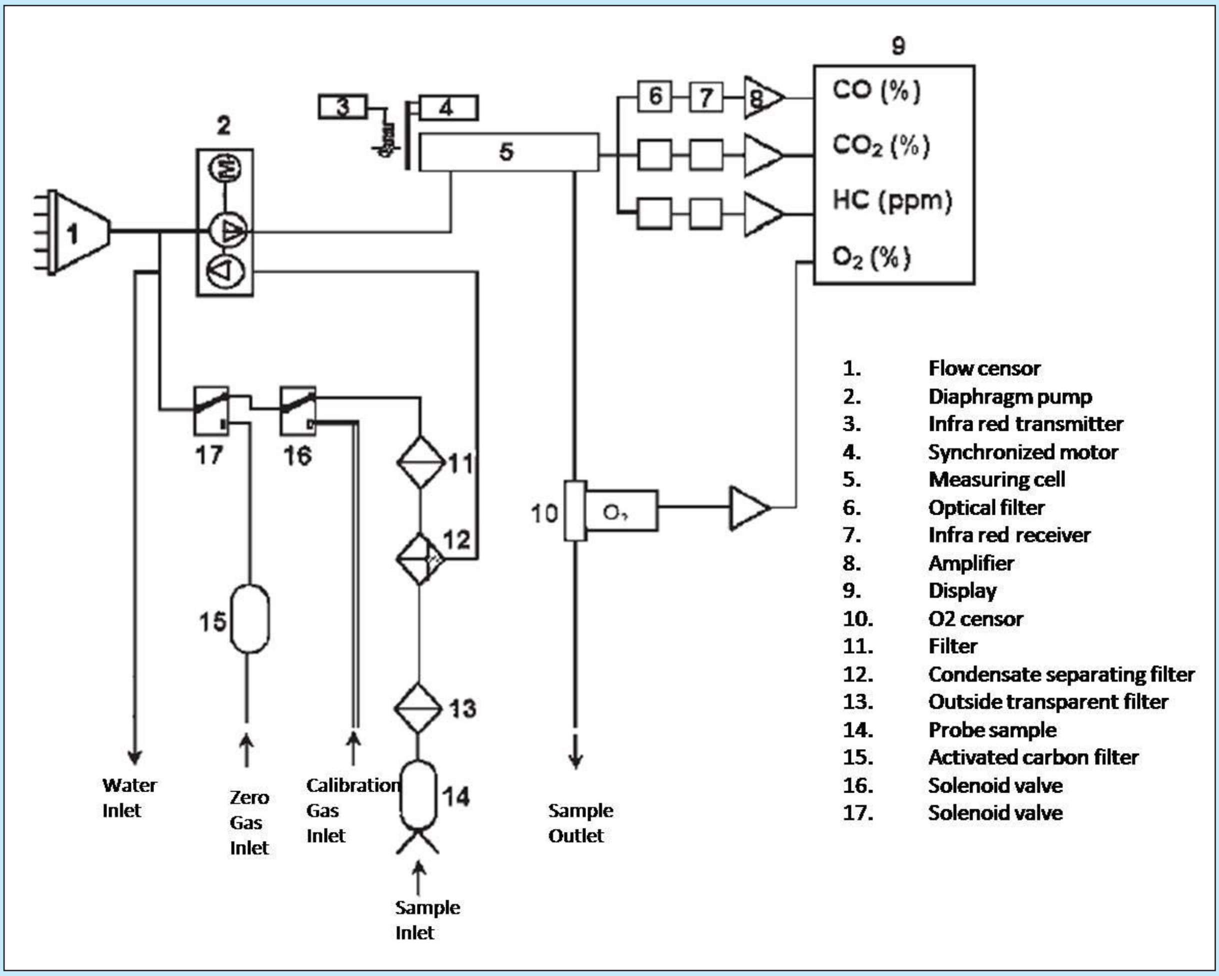

Figure 1
Schematic diagram for exhaust gas emission experiment (SNI 19-7118.1-2005).

Standard (SNI 19-7118.1-2005). Figure 1 shows a schematic diagram for an exhaust gas emission experiment.

III. RESULTS AND DISCUSSION

A. Physical-Chemical Characteristics

A physical-chemical characteristics test was carried out on four different fuels, i.e. Diesel Fuel 48, B-100, B-20 and B-30. All parameters observed for Diesel Fuel 48, B-20 and B-30 were in reference to the Diesel Fuel 48 specification issued by the Directorate General of Oil and Gas, while parameters observed for B-100 were in reference to the Indonesian National Standard (SNI 7182:2015). Research shows that fuel properties such as viscosity, cetane number, distillation and calorific value affect diesel engine performance. Therefore, it is important to ensure the physical-chemical characteristic test result is completed and fulfilled the specification prior to doing the diesel engine performance test (Monyem and Gerpen 2001).

The physical-chemical characteristic test result for B-100 is shown in Table 2 and indicates that all parameters for B-100 are still in B-100 specification

Table 2
Physical-chemical characteristic test results of B-100 in accordance with Indonesian National Standard (SNI 7182:2015)

No.	Parameters	Units	Test Result	Limit		Test Method
				Min	Max	
1.	Cetane Number	-	62,4	51	-	ASTM D 613 ASTM D 6890
2.	Density at 40°C	kg/m^3	875	850	890	ASTM D 1298 ASTM D 4052
3.	Viscosity at 40°C	mm^2/s	4,65	2,3	6,0	ASTM D 445
4.	Sulphur content	mg/kg	100	-	100	ASTM D 5453 ASTM D 1266 ASTM D 4294 ASTM D 2622
5.	Distillation 90%	°C	360	-	360	ASTM D 1160
6.	Flash Point (closed cup)	°C	118	100	-	ASTM D 93
7.	Cloud Point	°C	-	-	18	ASTM D 2500
8.	Carbon residue in 10% distillation residue	% m/m	Nil	- -	0,05 0,3	ASTM D 4530 ASTM D 189
9.	Water and Sediment	% vol	Nil	-	0,05	ASTM D 2709
10.	Phosphor	mg/kg	10	-	10	AOCS Ca 12-55
11.	Copper Strip Corrosion (3 hours, 50°C)	Merit	1a	-	kelas 1	ASTM D 130
12.	Sulfated Ash	% mass	0,02	-	0,02	ASTM D 874
13.	Acid Number	mg KOH/g	0,6	-	0,6	AOCS Cd 3d-63 ASTM D 664
14.	Free Glycerol	% mass	0,02	-	0,02	AOCS Ca 14-56 ASTM D 6584
15.	Total Glycerol	% mass	0,24	-	0,24	AOCS Ca 14-56 ASTM D 6584
16.	Methyl Esther Content	% mass	96,5	-	96,5	SNI 7182:2012
17.	Iodine number	% mass	115	-	115	AOCS Cd 1-25
18.	Oxidation Stability Induction Period by Rancimat method; or Induction Period by Petro Oxy	Minutes	612	360 27	- -	EN 15751 ASTM D 7545

Table 3
Physical-chemical characteristic of B-0, B-20 and B-30

No	Parameters	Unit	Limit*)		Test Result			Test Method
			Min	Max	B-0	B-20	B-30	
1	Cetane Number		48	-	47.5	49.2	56.4	ASTM D 613
	Cetane Index		45	-				D 4737
2	Density at 15 °C	kg/m³	815	860	852	857	859	D 4052/D1298
3	Viscosity at 40°C	mm²/s	2.0 – 4.5		3.06	3.22	3.38	D 445
4	Sulphur Content	% m/m	-	0,35 1) 0,30 2) 0,25 3) 0,05 4) 0,005 5)	0.108	0.083	0.074	D 5453 or D 4294
5	Distillation: 90% vol. evaporation	°C		370	344.5	347	345	D 86
6	Flash point	°C	52		60	64	70	D 93
7	Pour point	°C		18	6	3	3	D 97
8	Carbon residue	% m/m	-	0.1	Nil	Nil	Nil	D 5430
9	Water content	mg/kg	-	500	88.26	178.96	216.6	D 6304
10	Biological Growth *)		Nil		Nil	Nil	Nil	
11	FAME content *)	% v/v	-	-	0.49	20.1	30.9	D 7806
12	Methanol content *)	% v/v	Undetected		Undetected			D 4815
13	Copper strip corrosion	merit	-	Class 1	1a	1a	1a	D 130
14	Sulfathed Ash	% m/m	-	0.01				D 482
15	Sediment content	% m/m	-	0.01	Nihil	Nihil	Nihil	D 473
16	Total acid number	mg KOH/gr	-	0.6	0.004	0.0058	0.0088	D 664
17	Total strong acid	mg KOH/gr	-	0	0	0	0	D 664
18	Appearance	-	Clear and bright		Clear and bright			Visual
19	Colour	No. ASTM	-	3				D 1500
20	Lubricity (HFRR wear scar dia @60°C)	micron	-	460 6)	291	268	251	D 6079

*) Regulation issued by Directorate General of Oil and Gas of Government of Indonesia No. 28.K/10/DJM.T/2016

based on SNI 7182:2015. In addition, B-100 has a higher cetane number (62.4) than Diesel Fuel 48.

The physical-chemical characteristic test result for Diesel Fuel 48 (B-0), B-20 and B-30 is shown in Table 3. The table exhibits the specifications based on the government requirements. Cetane number for Diesel Fuel 48 obtained 47.5, slightly lower than the minimum limit; however it still fulfilled the specification because according to the ASTM D 613 an acceptable cetane number result is ± 0.5. For B-20, the cetane number (49.2) is slightly higher than Diesel Fuel 48 while for B-30, the cetane number (56.4) is significantly higher than Diesel Fuel 48. The increase of cetane number for both B-20

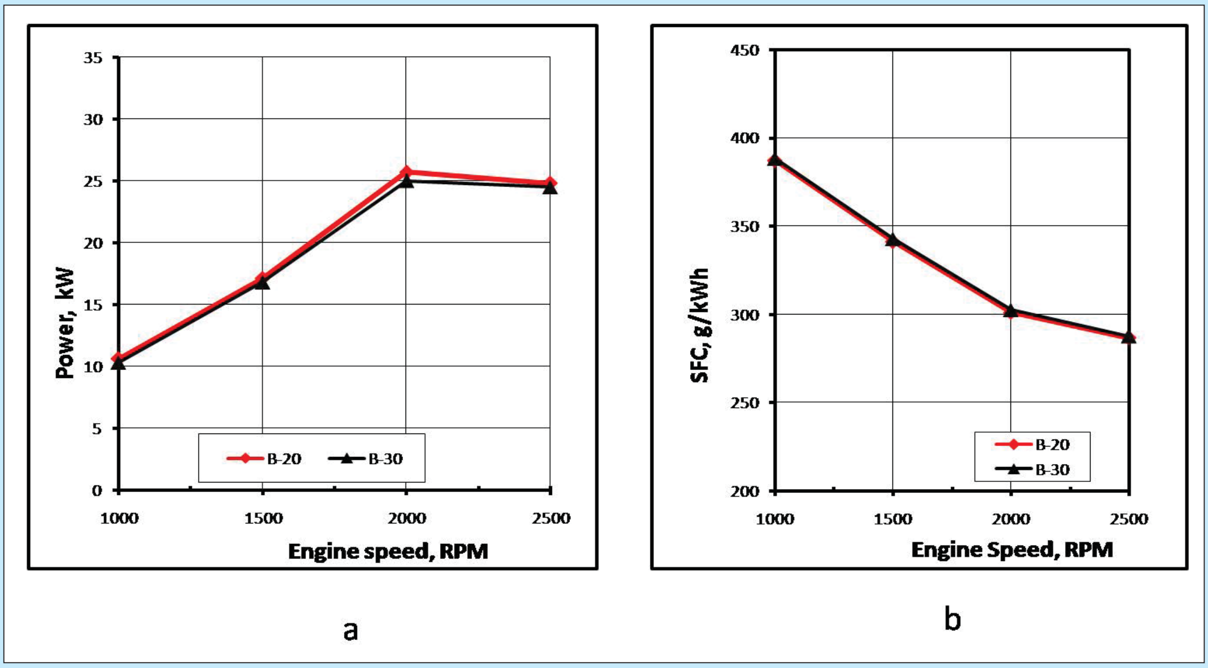

Figure 2
Comparison of B-20 and B-30 engine power (a) and SFC (b) with various engine speeds at half-load engine condition (1/2 throttle).

and B-30 occurred because B-100 as the mixture compound has a considerably higher cetane number (62.4) than Diesel 48. Another parameter which changed significantly with the addition of B-100 was sulphur content. From the physical-chemical characteristics test result, it is known that B-100 has a sulphur content of 100 ppm, while Diesel Fuel 48 has a sulphur content of 1080 ppm. The addition of approximately 30% biodiesel to Diesel Fuel 48 decreased sulphur content by up to 30%. A higher percentage blend of biodiesel has lower sulphur content. In this study, B-20 and B-30 has sulphur content of 830 and 740 respectively. Sulphur content is unfavorable in fuel because it can cause excess acid value and damage to the engine because of carbon deposits in the combustion chamber (Mei et al. 2003).

B. Diesel Engine Performance and Specific Fuel Consumption

This section will discuss engine power and fuel consumption for the diesel engine fuelled with B-20 and B-30. Three loads (1/2 throttle, ¾ throttle and full load) and various RPM were used in this performance. The B-20 and B-30 performance tests at full-load engine condition could be done up to 3500 rpm. However, a performance test at ¾-load engine condition (3/4 throttle) could be done only up to 3000 rpm and at half-load engine condition (1/2 throttle) only until 2500 rpm.

Figure 2 (a) shows when diesel engine fuelled with B-30, the power of the diesel engine performance at half-load engine condition decreased by 2.13% compared to the diesel engine fuelled with B-20. Similar results were reported by Kaplan et al. (2006), who compared sunflower-oil biodiesel and diesel fuels at partial loads and at different engine speeds in a diesel engine. Their results showed about 5% power reduction. They also explained this power reduction with lower heating value of the biodiesel. In contrast, SFC of diesel engine fuelled with B-30 is slightly higher than B-20 by 0.37% as shown in Figure 2 (b). An SFC test is necessary for evaluating the fuel consumption pattern of an engine. This test was used to confirm that both the engines are going to perform similarly, when subjected to the same fuel (Agarwa et al. 2003). Hence, when different fuels (B-20 and B-30) are used for running the similar engines under similar operating conditions, any marked difference in their performance is due to the characteristics of the fuel alone. Therefore, engines with higher biodiesel mixture have lower power but higher SFC because biodiesel and its blend have lower heating value, higher density and higher viscosity than conventional diesel, as shown in Table 3.

Figure 3 (a) shows when a diesel engine is fuelled with B-30, the power of the diesel engine performance at 3/4-load engine condition decreased by 1.80% compared to a diesel engine fuelled with B-20. In contrast, the SFC of diesel engine fuelled with B-30 is slightly higher than B-20 (by 0.88%) as shown in Figure 3 (b). The trends are similar between half load and 3/4-load engine condition for engine power and SFC.

Figure 4 (a) shows the variation in engine power at full-load for B-20 and B-30. The results show when a diesel engine is fuelled with B-30, the engine

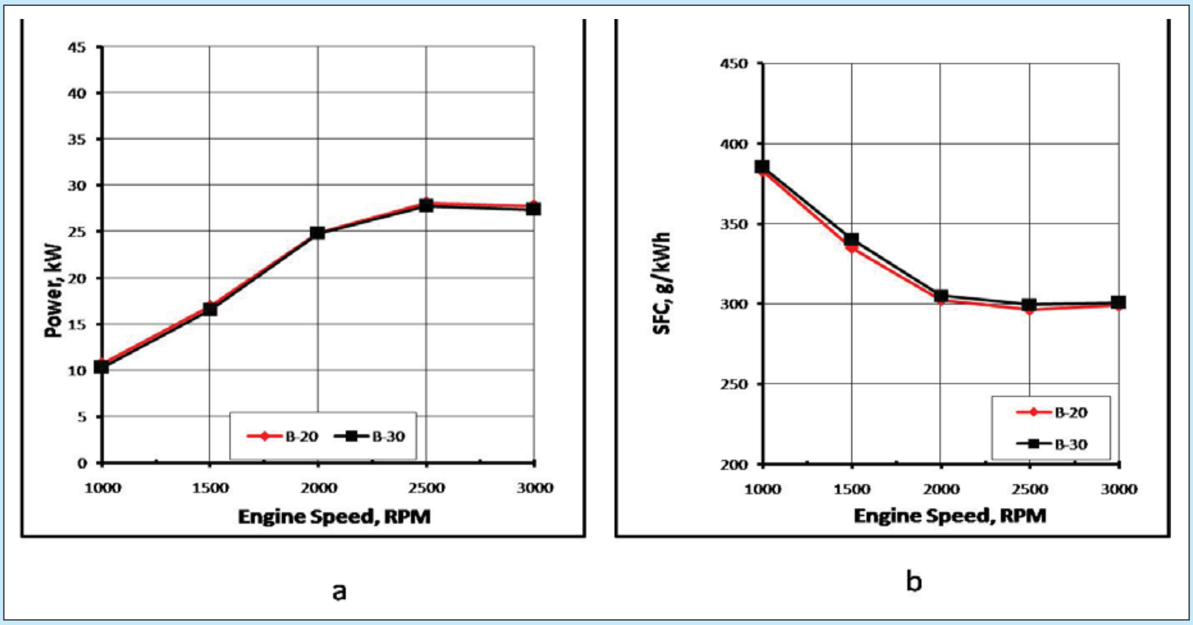

Figure 3
Comparison of B-20 and B-30 engine power (a) and SFC (b) with various engine speeds at 3/4-load engine condition (3/4 throttle).

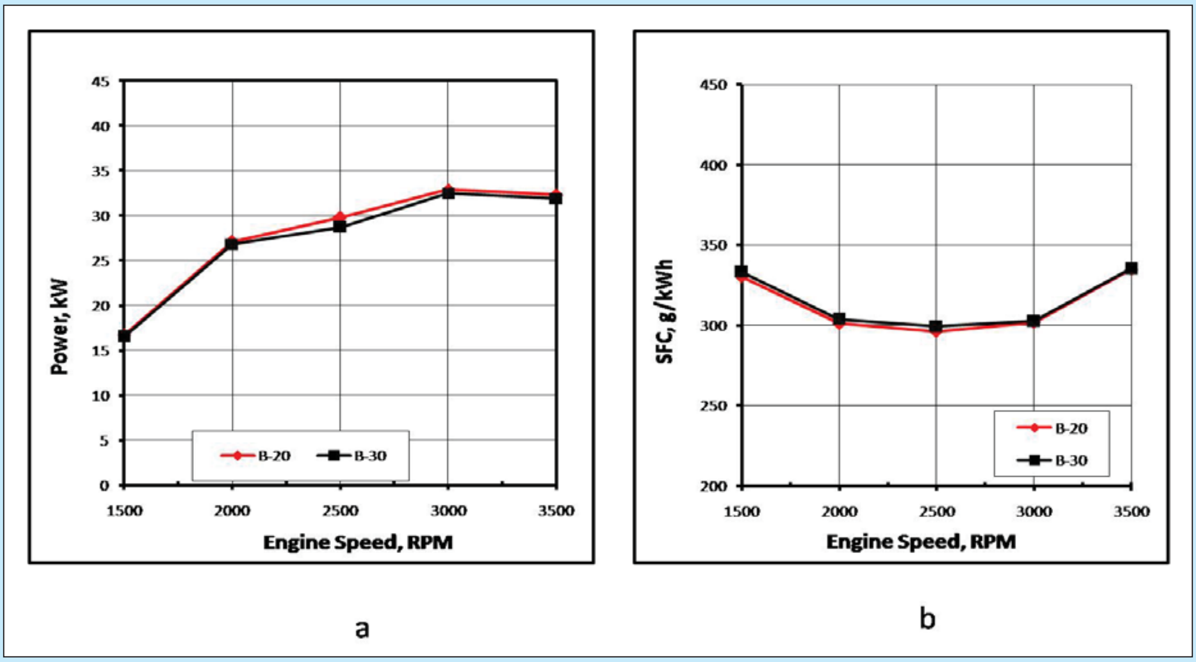

Figure 4
Comparison of B-20 and B-30 engine power (a) and SFC (b) with various engine speeds at full-load engine condition (full throttle).

Table 4
Summary of diesel engine performance and SFC test results

Load	RPM	Torque (Nm)		Power (Kw)		SFC (g/Kwh)	
		B-20	B-30	B-20	B-30	B-20	B-30
1/2 Throttle	1000	103.1	102.8	10.6	10.3	387.1	388.1
	1500	109.4	108.3	17.1	16.8	341.2	342.7
	2000	119.1	118.7	25.7	25.0	301.0	302.5
	2500	109.3	108.8	24.8	24.5	286.6	287.4
3/4 Throttle	1000	103.1	102.7	10.7	10.3	382.9	385.1
	1500	110.3	109.7	16.9	16.5	335.1	340.4
	2000	119.3	117.3	24.9	24.8	302.6	305.1
	2500	108.4	107.8	28.1	27.8	296.9	299.6
	3000	99.1	97.9	27.8	27.4	299.1	300.6
4/4 Throttle	1500	108.9	108.2	16.7	16.5	330.3	333.1
	2000	117.0	116.6	27.1	26.8	301.2	303.9
	2500	109.6	109.0	29.8	28.7	296.1	299.2
	3000	99.5	98.7	32.9	32.5	301.9	302.5
	3500	98.4	97.0	32.3	31.9	334.8	335.2

Table 5
Exhaust gas emission (Opacity) test result

Fuel	Opacity Emisstions (%)
B-20	50.6
B-30	47.2

power decreased by 1.69% compared to a diesel engine fuelled with B-20. Lin, et al. (2009) shows that engine power at full load condition decreases by 1.49% when using vegetable oil methyl esther as biodiesel feedstock. Ozsezen et al. (2009) reported that there was slight decreases in engine power at full load condition when using waste palm oil and canola oil as biodiesel feedstock. It is shows that various feedstocks show similar trends in engine power when using biodiesel as fuel. At full load condition, the SFC of a diesel engine fuelled with B-30 is slightly higher than B-20 by 0.62% as shown in Figure 4 (b). It is reported that in addition to lower heating value, higher density and higher viscosity of biodiesel, a higher SFC may also be affected as the biodiesel percentage increased in the blends (Song and Zhang 2008). A summary of diesel engine performance and SFC test results are shown in Table 4.

Table 4 indicates that maximum torque is obtained at 2000 rpm for each kind of fuel. At various engine speeds, the torque delivered with B-20 fuel was higher by approximately 0.5 Nm on average than the torque delivered by B-30 fuel. The higher viscosity of B-30, which may affect the engine brake effective power and engine torque especially in full-load conditions, increases the mixture momentum and consequently penetration depth in-cylinder. On the other hand, the higher viscosity and surface tension of biodiesel prevents sufficient breaking of the biodiesel during the injection process (Buyukkaya 2010).

C. Exhaust Gas Emission

Automotive exhaust gas emissions are commonly considered as the main cause of air pollution and main contributor of smog. The combustion process of a diesel engine produces darker smoke than a gasoline engine. This section will discuss the diesel engine emissions for the two fuels (B-20 and B-30). The engine emissions measured were smoke opacity. The condition of the test was in idle condition with no load but acceleration. When the engine is fuelled with B-30, the smoke opacity reduction is moderately lower (dropped by 6.71%) compared to B-20 as shown in Table 5. Biodiesel contains 10% oxygen while diesel has no oxygen content. An increased amount of oxygen in a fuel rich combustion zone is believed to ensure more complete combustion and therefore reduces exhaust emissions (Fazal et al. 2011). It is obvious that B-30 has more oxygen content than B-20. As the oxygen content increases, a larger fraction of the fuel carbon is converted to CO in the rich premixed region rather than soot formation (Qi et al. 2010). It is also reported that emission reduction of biodiesel is due to lower aromatic and sulphur compounds and higher cetane number for biodiesel, but oxygen content is the most important factor. It should be noted that the advantage of lower sulphur characteristics in biodiesel will disappear in the future as sulphur content in diesel fuel is becoming less over time. (Xue 2011).

IV. CONCLUSION

Biodiesel produced from renewable and domestic sources (palm oil), represents more sustainable energy and as a result it will play a significant role in meeting energy requirements especially for transportation and industry. Our research shows that the physical-chemical characteristics of B-30 are similar to Diesel fuel 48 (conventional diesel), even though it has a better cetane number and lower sulphur content. Accordingly, it is better for the environment. Our research also found that B-30 has 1.69% lower engine power and 0.5 Nm lower engine torque at full load condition compared to B-20. However, specific fuel consumption of B-30 is 0.62% higher than B-20 due to a low heating value, high density and the viscosity of biodiesel. It also identified that the blends of biodiesel could help in controlling air pollution since the smoke opacity result is decreasing by 6.71% when using B-30. Small blends of biodiesel are technically viable as alternative fuel in existing diesel engines with no or insignificant modification to the engine.

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