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Investigation on used oil and engine components of vehicles road test using twenty percent Fatty Acid Methyl Ester (B20)

Ihwan Haryono, Muhammad Ma'ruf, Hari Setiapraja

The Center for Thermodynamics, Engines and Propulsion System, PUSPIPTEK Area, Build. 230, Serpong, South Tangerang, Indonesia.

Abstract
The Indonesian government has mandated to utilize biodiesel at the Indonesian market with blend ratio of 20% biodiesel and 80% diesel fuel (B20). This policy bring car manufacturers concerning in using B20 effect on the engine life time. To evaluate the effect of using B20 on engine components, vehicles road test has been done along 40,000 KM. The test was using three brands of vehicles, in which each brand was composed of two identical vehicles fuelled by B20 FAME fuel and pure diesel fuel (B0) (solar). During the road test at certain intervals in accordance with the manufacturer's maintenance recommendations, the vehicles lubricating oil replacement and other routine maintenance were required. At the completion of the test all test vehicles to be dismantled and the engine components inspected. The test results show that the most parameter of used oil lubricants still in the limits. Likewise, the condition of the vehicles engine components did not show significant difference between using the pure diesel or B20.

Keywords: Biodiesel; Used oil; Engine component; Deposit; Wear.

1. Introduction
Facing the scarcity of fuel resources and reducing subsidized national budgeting in consuming fuels, the government has decided to implement biodiesel 20% (B20). While most of diesel vehicles technology in the society is designed to adapt with biodiesel blends ratio up to 7.5 % in diesel fuel. Therefore, use of B20 resulted in the vehicle manufacturers concerned about the effect on the engine components. Besides being a renewable and domestic resource, biodiesel reduces most emissions while engine performance and fuel economy are nearly identical compared to conventional fuels. Knothe et al. has overviewed several problems which arise from utilization of biodiesel from various aspects such as economics, combustion, some emissions, lube oil contamination and low temperature properties [1]. There are uncertainties regarding the effect of biodiesel on engine components durability due to its variation of the physical-chemical properties of biodiesel in comparison to commercial diesel fuel. Tschöke reported that an irreversible oil dilution appears in the engine lubrication system as a result of regeneration mode of current passenger car diesel engines with particulate filters. The oil dilution decrease of the viscosity results with the risk of increasing wear. This fuel dilution is due to higher distillation characteristic of biodiesel in comparison with diesel fuel [2].

Many of the parts in the diesel fuel injection system are made of high-carbon steels and thus are prone to corrosion when in contact with water. ASTM D 2709 is used to measure the total amount of water and sediment in a diesel fuel sample and limits the amount of water and sediment to 0.05% (500 ppm). However, when fuels are exposed to high temperatures and the oxygen in air, they can undergo chemical changes that form insoluble compound in the fuel. These compounds form varnish deposits and sediments that can plug orifices and coat moving parts causing them to stick. Inorganic materials present in the fuel may produce ash that can be abrasive and contribute to wear between the piston and cylinder. The ASTM specification for biodiesel, D 6751, requires that ASTM D 874 be used. This method measures sulfated ash, which is specified because it is more sensitive than ash from sodium and potassium. These metals are likely to be the main sources for ash in biodiesel. Gerpen J.V., et al. [3]. Viscosity is the most important property of bio-diesel since it affects the operation of various engine components, particularly at low temperatures when the increase in viscosity affects the fluidity of the fuel.

There are some studies on biodiesel with blend ratio of 20 % by volume (B20). A review paper has been reported by Xue et al., explained much experimental results the effect of using biodiesel on the engine performances and emissions [4]. From the conclusion, the use of biodiesel could reduce in PM, HC and CO emissions with the imperceptible power loss, the increase in fuel consumption and the increase in NOx emission on conventional. They reported also that using biodiesel had positive effect on the deposit formation and engine component condition. Pethkar et al. [5] have discussed the effect of biodiesel on diesel engine performance, lubricants and emissions. From these reports, the effect of biodiesel on engine power, durability and emissions and the corresponding effect factors are surveyed and analyzed in detail. The use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the insignificant power loss, the increase in fuel consumption and the NOx emission on conventional diesel engines with no or less modification. Moreover, biodiesel also tends to reduce carbon deposit and wear of the key engine parts. They suggested that the further studies on biodiesel engine endurance tests need be done to make clear the reason and mechanism of wears. Schumacer et. al. have studied oil analysis of 12 vehicles fueling some variety and composition of biodiesels. The findings suggested that the biodiesel and biodiesel blend fueled engines were wearing at a normal rate [6]. Thorton et. al. have reported the impacts of biodiesel fuel blends oil dilution on light-duty diesel engine operation. After the completion of the durability tests for the NAC and the SCR system, the engine had undergone an accelerated aging schedule representative for approximately 240,000 miles, the engine was disassembled and each component was analyzed. None of the components of the engine, including the injectors, showed signs of excessive wear or other signs of deterioration as a result of the extended biodiesel operation. The flow characteristics of the injectors remained comparable to levels noted before the start of the durability study [7].

Heck et al. have reported a 2,000,000 mile evaluation of the performance and operational impacts of B20 biodiesel usage in a long-haul trucking company. The results showed that breakdown in fuel related mechanical system did not occur and engine oil performance was at not significant different condition for all evaluated trucks [8]. Raheman et al. conducted a performance test of a 10.3-kW single-cylinder water-cooled direct-injection diesel engine with blends of biodiesel (from a mixture of oils) and high-speed diesel for 100 h. Experiments were also conducted to assess soot deposits on engine components, such as cylinder head, piston crown, and fuel injector tip, and addition of wear metal in the lubricating oil of diesel engine when operated with the biodiesel blend. As compared with HSD-fueled engine, lesser carbon deposits on the in-cylinder parts (such as cylinder head, piston crown, and fuel injector) were observed for the B10-fueled engine due to better combustion of biodiesel blend. Lower concentrations of all heavy metals (such as Cu, Zn, Fe, Pb, Mg, and Al, except for Mn and Ni) in the lubricating oil of diesel engine were found in B10-fueled engine as compared with those in HSD-fueled engine [9].

In contrast, little studies reporting in negative effect using biodiesel relating to oil lubricant used and the engine components. Liaquat et al. [10] studied the impact of palm biodiesel blend on injector deposit formation on a single-cylinder, four-stroke diesel engine. The engine was coupled to an eddy current dynamometer. The endurance test was carried out for 250 h at 2,000 rpm and 10 Nm load on 2 fuel samples, DF and PB20. According to the results of the investigation, visual inspection showed some deposit accumulation on injectors for both fuels. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) analysis showed greater carbon deposits on and around the injector tip for PB20 compared to the engine running with DF. Similarly, lubricating oil analysis presented excessive wear metal concentrations, decreased viscosity and increased density values when the engine was fuelled with PB20. Negative effect was also reported by Fraer R., et al. [11] in operating the Mack Tractors. Analysis of vehicle operation and engine teardown showed several differences between B20 and petroleum diesel. The cylinder heads of the B20 engines contained a heavy amount of sludge around the rocker assemblies that was not found in the diesel engines. Out-of-specification fuel is the suspected cause. Both B20 engines required injector nozzle replacement over the evaluation and teardown period, which may be attributable to B20. But, these differences were not observed with the Ford cargo vans. The Ford vans did not have the filter plugging, injector replacement, or sludge accumulation issues noted with the Mack tractors.

In order to evaluate the effects of the usage of biodiesel, with blend ratio of 20% pure biodiesel and 80% pure low grade diesel fuel (solar), road test was conducted with 6 six vehicles from three different manufactures. This test was collaboration among stakeholder in Indonesia including government, university, bio-fuel producer, an Indonesian oil company and association of automobile industry. This paper reports the results of utilization of B20 on engine components and lubricant from six vehicles after road test of 40,000 kilometers.

2. Test method

Testing were conducted using 3 types of vehicles, with specification as shown in Table 1, in which each brand consists of 2 units of vehicles that can be considered identical. The mileage for vehicle A had a distance of about 100,000 KM, vehicle B was a new vehicle and still in the run-in condition, and vehicle C was still relatively new condition with mileage less than 3,000 KM. Selection the type and condition of the vehicle was according to the recommendation from The Association of Indonesian Automotive Industries (GAIKINDO) based on the consideration to represent vehicles available in the Indonesian market.

In this road test, each types of vehicles were using blended fuel B20 (20% biodiesel) and pure low grade diesel fuel, B0 (diesel 48) for comparison. The biodiesel was produced by a company associated to APROBI (Indonesian Bio-fuel Producers Association) and B0/Solar 48 produced by Indonesian oil company (PERTAMINA). Both test fuels were enclosed by a Certificate of Analysis (CoA) which fulfilled the Indonesia National Standard (SNI) [12]. Repetition tests were done during road test for validating the quality of the blended fuel (B20) as well as B100 and B0 fuels to ensure that vehicles were fuelled with the same fuel quality. (Table A1 and A2 (appendix)) show the Indonesian standard for biodiesel qualities and diesel fuel/solar 48 with the results of quality measurements respectively [13].

Table 1. The test vehicle used during the road test.

Engine Specification	Vehicle A	Vehicle B	Vehicle C
Capacity (cc)	2500	1300 cc	2500
Type	4 cylinder, in-line with 16 valves	4 cylinder, in-line with 16 valves	4 cylinder, in-line with 16 valves
Fuel System	common rail	common rail	common rail
Air Supply	Turbocharge	Turbocharge	Turbocharge
Emissions treatment	EGR	EGR	EGR
Transmission	Manual	Manual	Automatic

Before the road testing, all three vehicles were reconditioned especially on the component related to fuel system to ensure that whole tested vehicles at the same condition.

For vehicle A, various components around the combustion chamber such as the pistons, inlet and outlet valves, injector tips, lubricants and oil sump were cleaned. For ring sets, stem seals, fuel and oil filter were replaced with new ones. While, for vehicles B reconditioning was done by spraying the cleaning chemical liquid as recommended by manufacture.

For vehicles C, all components associated with combustion systems such as fuel hose, piston and ring sets, inlet and outlet valves, end bearings, stem seals, fuel and oil filters were replaced with new ones. For cylinder block, injector tips, and oil sump were cleaned. All the components were reassembled and filled new lubricant as recommended by the manufacturer.

Road testing was conducted in about 3½ months until reach a mileage of 40,000 KM. All test vehicles were run in mileage around 550 - 570 KM per day with took a rest for 3 hours in area which has low temperature (around 15 deg C).
During the road test, vehicle oil change and maintenance were done periodically as the standard of maintenance recommended by the manufacturer, as shown in Table 2. After completion, all vehicle engines were dismantled and subsequently conducted an investigation and assessment of the components conditions.

Table 2. Activities relating to the oil analysis and investigation of engine components.

Activities	Road test B20 and B0 (in thousand kilometers)								
	0	5	10	15	20	25	30	35	40
Oil change & oil analysis, vehicle A	●		●						●
Oil change & oil analysis, vehicle B	●			●			●		●
Oil change & oil analysis, vehicle C	●		●	●	●	●	●	●	●
Engine components investigation	●								●
Components assessment									●

3. Result and discussions

Based on analysis of the fuel quality B0 and B100 shown in page Appendix, the specification and quality of each fuel (B0 and B100) has met the requirements set. Therefore, the influence of variation from tested fuel to vehicle performance, emission and engine component could be minimized. In this paper, the result of fresh oil and used oil analysis which including key parameters such as viscosity, TBN, wear metals and also visual inspection for several engine components will be discussed in the next section.

3.1 Used oil analysis

Used oil is considered plays important role in engine evaluation as it could show the process inside the engine during its operation. Oil analysis results of the some parameters presented in the following figures. The dashed line on the graph represents the limit value for each parameter which referred to some reference data, made possible vehicle manufacturer has its own limit value limit action in accordance with the specifications of the vehicle. Used oil analysis can become one of parameters for evaluating utilization of B20 related to maintenance period for engine manufacturer. Moreover, the results can be used as reference for manufacture to evaluate their engine oil specification or periodic oil change.

3.1.1 Viscosity

Figures 1-3 show viscosity analysis after its periodic oil change for vehicle A, B and C during road test. Each vehicle has difference oil periodic change recommendation. Periodic oil change for Vehicle A is every 10 thousands km, while for vehicle B and C are 15 thousands km and 5 thousands km respectively. Here, limit value for used oil viscosity is ± 25% of fresh oil viscosity which referred to CRC Handbook by Booser E.R. [14].
The used oil viscosity is lower compared with fresh oil for all vehicles at the whole periodic oil change, except for vehicle B at periodic of 40 thousand km. However, the values were still in the warning limit for all vehicles both fuelled with B0 and B20. Here, almost all of used oil viscosity for B0 and B20 vehicle did not show any significant different at almost all oil periodic change. For vehicle C, data on 10,000 km has no comparison to fuel B0 because of mishandling during periodic oil change. In general, the viscosity parameter changes were relatively small. It shows an indication that the level of oxidation and contamination in the fuel lubricant using B0 and B20 were not much different.

3.1.2 Total Base Number (TBN)

Total base number of a lubricant is required as neutralizing acid derived from combustion or oxidation. TBN impairment occurred because alkaline additive present in the lubricant has been used to neutralize the acid. Value limit alert for TBN is -75% of the value of fresh oil based reference data Semjonovs, J., et al. [15]. While based on the Handbook of Lubrication and Tribology provide a minimum limit of 2 mg KOH/g. Limit values shown on the graph is the value -75% of fresh oil. Figures 4-6 show TBN parameter of fresh oil and used oil for three vehicles during road test.

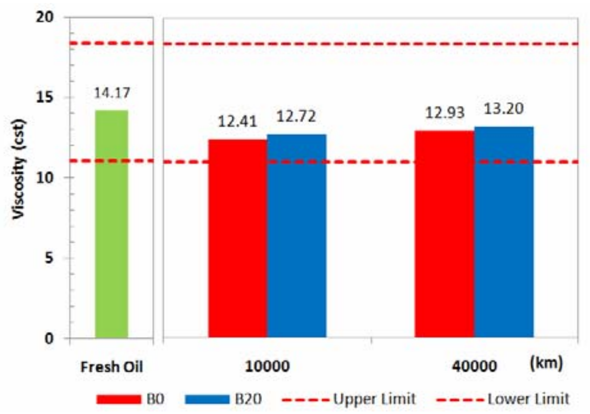

Figure 1. Viscosity of the vehicle A.

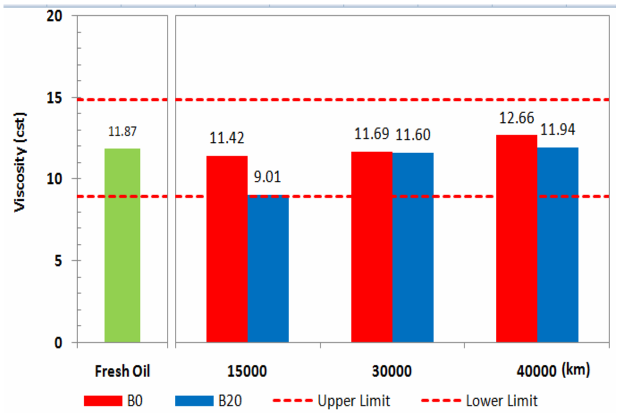

Figure 2. Viscosity of the vehicle B.

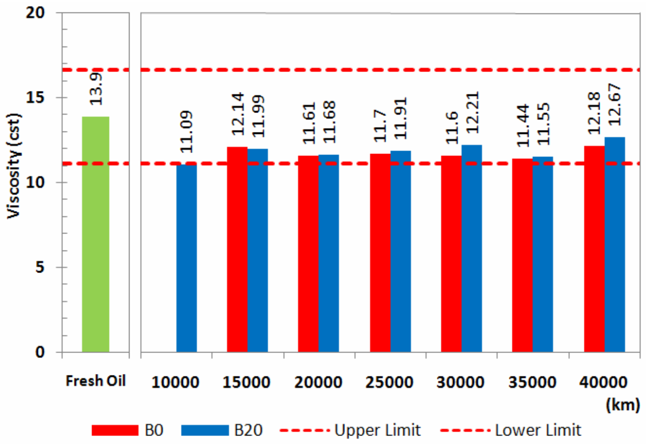

Figure 3. Viscosity of the vehicle C.

Figure 4 shows that TBN of used oil for vehicle A is still higher than the minimum warning limit that allowed neither by using B0 and B20 fuel. TBN for vehicle B on the mileage of 15,000 km for fuel B20 has exceeded the minimum limit warning as shown in Figure 5. TBN value of 0 indicates alkali in the lubricant has been used to neutralize the acid. It indicates that the usage of a lubricant was too long so that it requires immediate replacement. Replacement interval of the lubricant used for vehicles B needs to be shortened in order to meet the minimum threshold value TBN recommended. Figure 6 shows that TBN vehicle C was still within the minimum warning limit either by using B0 and B20 fuel. Here, data on 10,000 km had no comparison because the used oil of vehicle C fuelled with B0 was not sampled at the time of replacement of the lubricant. In general, TBN for all vehicles fuelled with B0 and B20 still meet the recommended limit during 40 thousands km road test, except for vehicles B at 15,000 miles.

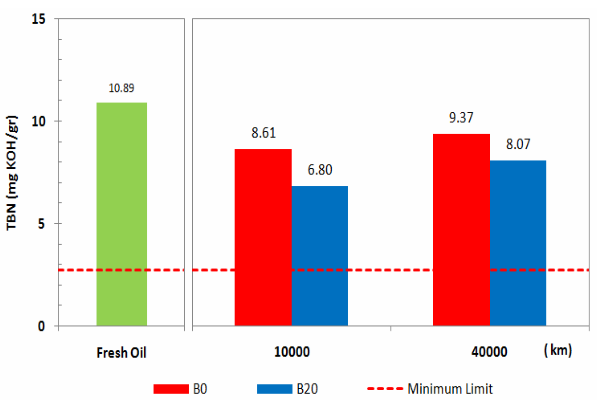

Figure 4. TBN for the vehicle A.

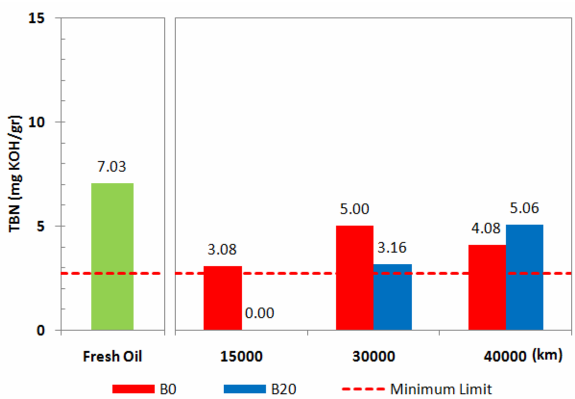

Figure 5. TBN for the vehicle B.

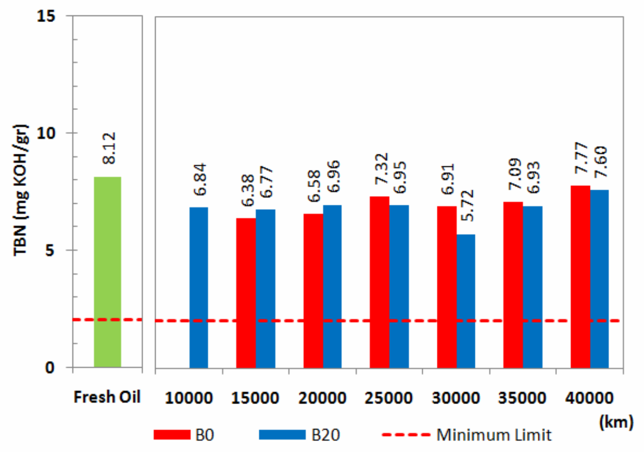

Figure 6. TBN for the vehicle C.

3.1.3 Wear metals

Figures 7-9 show metal wears analysis of vehicle A, B and C respectively. Action limits for wear metals were taken from the reference data Handbook of Lubrication and Tribology except for wear metals Na and Ni. Here, the limits were given by the testing laboratory in which the handbook does not mention the action limit for both of Na and Ni. Possible source of wear metals are presented in Table 3.

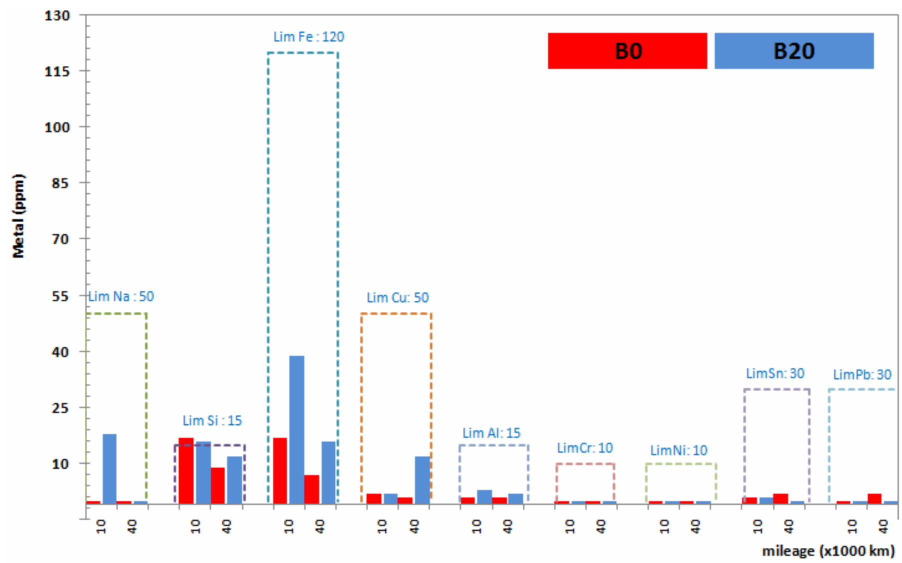

Figure 7. Wear metals analysis of the vehicle A.

In general, wear metals in the lubricant for vehicle A is still far below the recommended limits, except for Si at 10,000 km which slightly above the action limit for both of B0 and B20. Wear characteristics of Fe and Al tend to increase with the use of B20 fuel as shown in Figure 7. The result of wear metals in lubricant of the vehicle B, as shown in Figure 8, shows some metals were still below recommended limits. At some point mileage, Fe metal exceeded the recommendation limit, occurs at both of B0 and B20 fuels. Fe metal is most likely derived from the piston and valve components. The metal Si can be dust from the outside air or from the piston pins. Metal Al originating from piston and Cr can be wear from piston rings. Some wear metal values over the warning limits confirm that the used lubricant was already need replacement with shorter intervals.

The result of the wear metals in lubricant of the vehicle C, as shown in Figure 9, shows the metal content is far below the recommended limit except metal Si (B20) at one point mileage (10,000 KM) which exceeds the warning limit. Used oil analysis data of B0 on 10,000 KM was not taken so there is no comparative data for Si. Wear metal characteristics of Si and Fe in the vehicle C has a tendency to increase with the use of B20 fuel.

In general, the lubricants parameters were in the boundary limits, there were only a few points that exceed the given limits. The use of B20 fuel may improve some of the wear characteristics of the metal which is likely due to the corrosive nature of the degradation products of biodiesel. Shanta, S.M. et al. [17]. Moreover, for vehicle in which the replacement of oil lubricant change interval every 15,000 KM should be shortened or the lubricant to be replaced by better quality so that the limitation not to be exceeded.

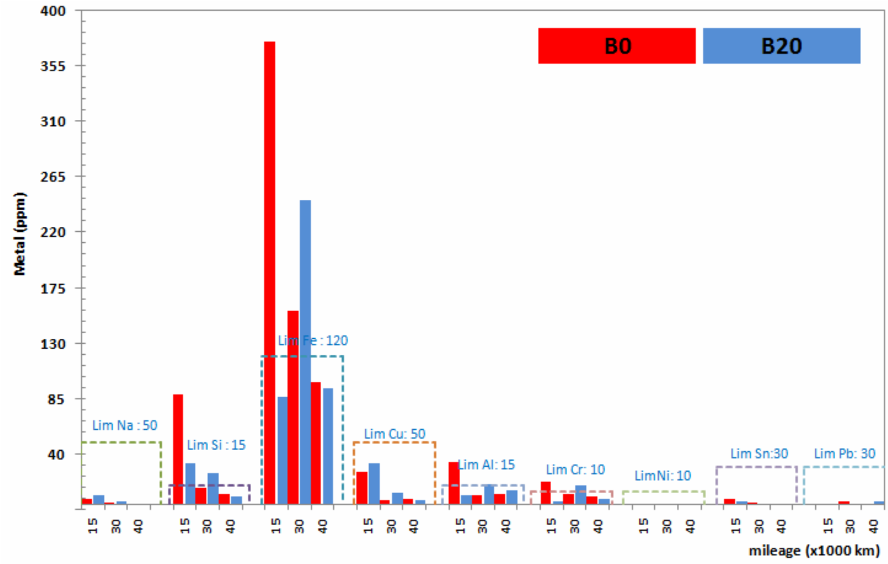

Figure 8.Wear metals analysis of the vehicle B.

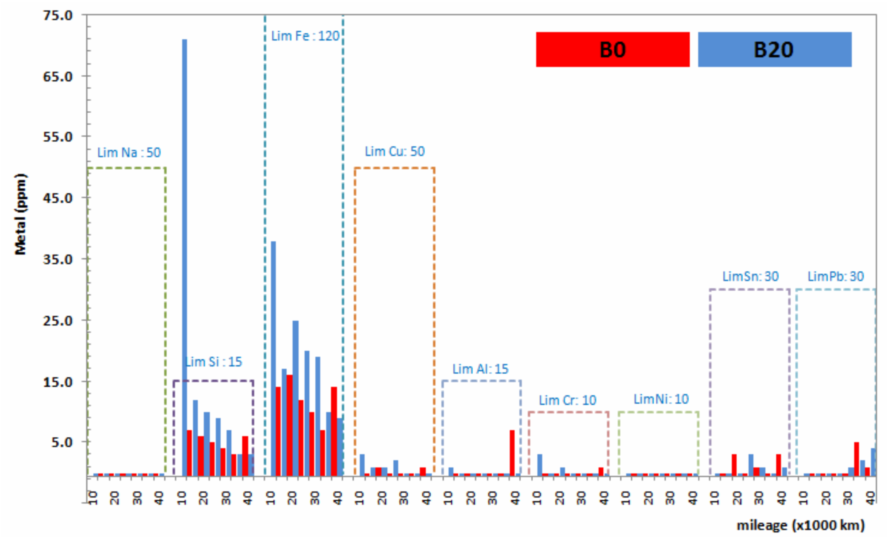

Figure 9. Wear metals analysis of the vehicle C.

Table 3. Possibility sources of wear metals. Evans J. [16].

Wear metals	Engine components
Iron, (Fe)	Pistons, cylinder liners, crank, camshaft, valves, rockers, rings, bearings, gears, shafts, etc
Chromium, (Cr)	Cylinder liners, piston rings, cooling system
Copper, (Cu)	Crankshaft, bearings, bushings, camshaft bearings, gear, oil coolers
Lead, (Pb)	Bearings, fuel additive
Almunium, (Al)	Pistons, bearings, crankcase & gear housing
Silicon, (Si)	Dirt, dust, defoamant, pistons
Sodium, (Na)	Coolant leak

3.2 Engine components inspection

The road testing was conducted without any significant problems. After completion of the 40,000 KM road testing, all the engines were completely disassembled. Investigations were done for the ring conditions, deposit formations on the critical components and others abnormal condition. The investigation results are shown in Table 4.

3.2.1 Ring sticking

The ring sticking was the first investigation of the engine component after completing the test. Deposits are formed by a combination of blow-by, lube oil and heat. Soft deposits can reduce clearances while hard deposits can transmit loads as well as reduce clearances. If deposits had reduced clearances essentially to zero, the ring sticks and usually ring breakage occurs. The effect of deposits in the oil ring is plugging, and as the deposits harden, this results in loss of unit pressure on the cylinder wall, sticking together of multiple piece oil rings and finally sticking in the groove. After completion of 40,000 km road test, there was no significant different on ring sticking between vehicle fuel with B0 and B20, moreover B20 show tendency to have better effect on oil ring life times.

3.2.2 Carbon deposit

Deposit is generally originating due to the thermal and oxidative degradation of lubricants and pyrolysis/incomplete combustion. These deposits degrade engine performance, efficiency, and cause operational problems and also increase maintenance. Sometimes heavy deposits may also lead to engine failure. Sinha S and Agarwal A.K. [18]. The utilization of biodiesel fuel (B20) was feared on the deposit formation in the engine due to its higher viscosity and distillation temperature compared to diesel fuel. From the pictures (Table 4) can be seen that carbon deposits on the piston side, piston crown, cylinder head, injectors tip, and inlet valve is insignificant different between B0 and B20.

3.2.3 Sludge

Sludge usually found in the cooler areas of the engine, while coke or varnish deposits tend to form in the hotter areas. Sludge deposits tend to be relatively soft and are usually found in the engine crankcase and sump, cam and/or valley covers (on V configuration engines). In extreme cases, when these deposits form in the “bottom end” of the engine they can partially (or in some cases completely) block the oil pump pick-up screen and oil ways, resulting in reduced oil supply and subsequent damage to critical engine components. Sludge deposits around the valve operating mechanism may result in sticking valves, and any reduction in oil flow can affect their operation resulting in noisy operation and/or reduced engine performance. A reduction in oil flow to the components may also result in premature wear. Investigation resulted on vehicle fuelled with B0 and B20 were in clean condition and cannot be distinguished between both of the B0 and B20.

3.2.4 Wears

The investigation for occurring wears were found light scratches on the end bearings of the vehicle B and C for both fuelled with B0 and B20 as well as a fairly heavy wear on the piston and the cylinder 3 on the vehicle C with B0. However, this condition was supposed to be a result of vehicle operating conditions not related to the use of biodiesel fuel.

In general, Utilization of B20 on modern diesel vehicle with common rail system, turbo charging and EGR were found no significant effect to its engine components. The results show that engine component for both vehicle fuelled B0 and B20 were at identical condition after reach 40,000 km. It was also expected that using biodiesel as recommended specification would result in optimum engine operation and condition. Table 4 shows the summary from observation of utilization B0 and B20 at 40,000 km for all vehicles related to the effect on engine components.

Table 4. Results of the components investigation after road testing.

	B0	B20
	• All piston ring, either 1st and 2nd for all cylinder, was in free conditions • Deposit in combustion chamber in moderate level • Wear in cylinder liner and piston wear normal, no scratch found • Sludge in oil sump was relatively clean	• Ring 1st for cylinder 1, 3 were sluggish, ring 1st cylinder 2, 4 were light stuck and the others were in free condition. • Deposit in combustion chamber in moderate level • Wear in cylinder liner and piston were normal, no scratch found • Sludge in oil sump was relatively clean
Vehicle A		

Table 4. Continued.

	B0	**B20**
	• Rings in cylinder 2 were light stuck and all ring on the other cylinders were sluggish • Sealing of the piston ring were good • Combustion chamber deposit was moderate/ normal • No corrosion on the injectors holders • Big end bearing (upper) for all cylinder were black and light scratches • No significant wear either on the piston or cylinder liner • Oil sump was clean	• All ring of all cylinders were sluggish • Sealing of the piston ring were good • Corrosion of all the injector holder • Combustion chamber deposit was moderate/ normal • Big end bearing (upper) for all cylinder were black and light scratches • No significant wear either on the piston or cylinder liner • Oil sump was clean
Vehicle B		

Table 4. Continued.

	B0	B20
	• Rings in cylinder 3 were light stuck and all ring of the other cylinders were sluggish • Heavy wear (scuff) on the piston for cyl. 3 • Heavy wear (scuff) on the liner for cyl. 3 • Scratches for big end bearings. • Combustion chamber deposit was moderate/normal	• Only ring 2nd of cylinder 2 was sluggish and all ring of the other cylinder were free conditions • Scratches for big end bearings. • Combustion chamber deposit was moderate/normal
Vehicle C		

4. Conclusion

Utilization of B20 Fatty Acid Methyl Esther over 40,000 KM road test showed no adverse effects on the lubricant properties which represented by parameter of viscosity, TBN and wear metals. However, for vehicles with lubricant change intervals every 15,000 KM, changing oil period should be shortened or improved lubricants quality to anticipate contamination of corrosive wear metals that is catalytic to oxidation. Visual inspections of deposits, scratches and wears on engine components for B20 were comparable with B0. Hence, utilization of B20 with good control quality of B20 did not have negative effect on engine components.

Appendix

Table A1. Indonesian Standard for biodiesel fuel used and the quality test results.

No	Properties	Units	Test methods	Requirements	Test fuel
1	Density, 40 ^oC	Kg/m^3	ASTM D1298/D4052	850-890	855
2	Viscosity, 40 ^oC	mm^2/s (CSt)	ASTM D445	2.3-6.0	3.54
3	Cetane Number	Min	ASTM D613/D6890	51	63.6
4	Flash point (open cup)	^oC, min	ASTM D93	100	164
5	Cloud point	^oC, max	ASTM D2500	18	16
6	Copper strip corrosion (3 hours at 50 ^oC)		ASTM 130	No. 1	1a

7	Carbon residue		ASTM 4530/D189		
	- In per original sample	%wt, max		0.05	Nil
	- In 10% distillation residue			0.3	
8	Water and sediment	%vol, max	ASTM D2709	0.05	-
9	Distillation temp. 90%	^{o}C, max	ASTM D1160	360	360
10	Sulfated ash	%wt, max	ASTM D874	0.02	-
11	Sulphur	mg/Kg, max	ASTM D5453/D-1266/D4294/D2622	100	0.007
12	Phosporus	mg/Kg, max	AOCS Ca 12-55	10	0.55
13	Acid number	mgKOH/gr,max	AOCS Cd 3d-63/ASTM D664	0.6	0.18
14	Free glycerol	%wt, max	AOCS Ca 14-56/ASTM D6584	0.02	
15	Total glycerol	%wt, max	AOCS Ca 14-56/ASTM D6584	0.24	0.002
16	Methyl ester content	%wt, min		96.5	-
17	Iodine number	%wt (g-12/100g), max	AOCS Cd 1-25	115	29.27
18	Oxidation stability				
	- Induction period by Rancimat method		EN 15751	360	>1440
	- Induction period by Petro Oxi method		ASTM D7545	27	

Table A2. Indonesian Standard for diesel fuel used (Solar 48) and the quality test results.

No	Properties	Units	Test methods	Require ments	Test fuel
1	Cetane				
	- Cetane Number	-	ASTM D613-95	Min 48	48.8
	- Cetane index	-	ASTM D4737-96a	Min 45	46.2
2	Specific gravity (at 15 ^{o}C)	Kg/m^3	ASTM D1298/D4052-96	815-870	855.6
3	Viscosity, 40 ^{o}C	mm^2/s	ASTM D445-97	2.0-5.0	3.35
4	Sulfur content	%m/m	ASTM D2622-98	Max 0.35	0.289
5	Distilation: T95	^{o}C	ASTM D86-99a	Max 370	361.5
6	Flash point (open cup)	^{o}C	ASTM D93-99c	Min 60	73
7	Pour point	^{o}C	ASTM D97	Max 18	-3
8	Carbon residue	%m/m	ASTM D4530-93	Max 0.1	Nil
9	Water content	mg/Kg	ASTM D1744-92	Max 500	350
10	Biologycal growth	-		None	Nil
11	FAME content	%v/v		Max 10	0.2
12	Methanol dan ethanol content	%v/v	ASTM D4815	Not detected	
13	Copper strip corrosion	Merit	ASTM D130-94	Max class 1	1a
14	Ash content	%v/v	ASTm D482-95	Max 0.01	0.003
15	Sediment content	%v/v	ASTM D473	Max 0.01	Nil
16	Strong Acid Number	mgKOH/g	ASTM D664	0	
17	Total Acid Number	mgKOH/g	ASTM D665	Max 0.6	0.047
18	Particulat	mg/l	ASTM D2276-99	-	
19	Apparence	-		Clear and bright	clear
20	Color	No. ASTM	ASTM D1500	Max 3.0	2

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Ihwan Haryono getting Bachelor degree in 1995 from Brawijaya University of Malang Indonesia in Mechanical Engineering and master degree in 2005 from Agricultural University of Bogor, Indonesia, with major in agricultural engineering science. Since 1997 until now, he work as a researcher in The Center of Thermodynamics, Engines and Propulsion System at South Tangerang, Indonesia. Some publications have been published related to biodiesel and engine components inspection. He is also a member of Researchers Association in which coordinated by Indonesian Institute of Science. The current research are about the application of alternative fuels on the vehicles and marine ship.
E-mail address: ihwan.haryono@bppt.go.id

Muhammad Ma'ruf received his BS Degree in 2007 in chemistry science from Gadjah Mada University, Yogyakarta-Indonesia, and received his MS Degree (2015) in Mechanical Engineering - Energy Conversion from Indonesia University. In 2010, he joined the Center for Thermodynamics, Engines and Propulsion System as test engineer for vehicle & engine emission certification. Since his work, he has been involved in several research related to application of biodiesel in automotive diesel engines and has several papers on this topics. His current research interests are alternative & renewable fuels for vehicle.
E-mail address: muhammad.maruf@bppt.go.id

Hari Setiapraja received his Doctoral degree in 2012 in Energy and Environmental Systems from Hokkaido University, Japan. He has been involved in several research related to application of biodiesel in automotive diesel engines since 2000. His research mainly focus on improvement of performance and emissions of diesel engine fuelled with biofuel.
E-mail address: hari.setiapraja@bppt.go.id