INCREASING OF ENGINE OIL CHANGE INTERVAL BY USING ADDITIONAL OIL FILTER IN DIESEL ENGINES

Jevgenijs Semjonovs, Guntis Springis, Armands Leitans
Riga Technical University, Latvia
jevgenijs.semjonovs@rtu.lv, guntis.springis@rtu.lv, armands.leitans@rtu.lv

Abstract. Each moving part and cylinder walls in the internal combustion engine require clean oil for proper lubrication and lasting life. Engine oil is intended not only to lubricate the rotating parts, but also to cool, clean, and seal the critical engine components. It also aids in suspending wear metals and hard particles such as soot that is produced in the combustion process. However, with engine operation, engine oil degrades. Carmakers usually recommend that car owners change oil on the basis of driving hours or driving distance. Engine oil filters may assist to delay the time of oil replacement. If used properly, a lube oil and filter combination can reduce wear and prolong the life of an engine and its components. Especially for this research buses used in regular long-distance routes were equipped with additional bypass oil filters. The oil drain period was extended to see the influence of additional oil filter on the engine oil and engine wear. Oil samples were taken periodically and sent to the laboratory. According to the results of chemical analysis of oil samples conclusions were made. An additional filter helps remove very small particles suspended in the engine oil, that is why the wear processes are reduced. An additional filter helps delay degrading of engine oil, so the oil change interval can be prolonged.

Keywords: engine oil, oil filters, oil change intervals, analysis, lubrication, wear.

Introduction

Engine oils have the following functions [1].

1. To maintain the oil film, supply additives, and wash out debris such as wear metal from lubricated parts.
2. To remove heat from sliding surfaces and the related parts.
3. To seal the parts of piston rings and cylinder.
4. To clean engine internals and disperse sludge in oil.
5. To protect engine internals from rust and corrosion.

It is required that engine oils maintain all of the mentioned functions for a finite period of time. But with engine operation engine oil degrades. This is because the engine oil is subject to shearing of molecules, oxidation, nitration, and polymerization by heat plus contamination by fuel and blowby gas during circulation in the engine, all of which leads to deterioration. Continuous use of deteriorated engine oil for a long period will cause engine problems. Therefore, periodic oil change is required.

Engine oil is a very important data carrier about the general technical condition of the engine and its elements. Therefore, the analysis of engine oil helps carry out to the expert the express preliminary treatment of the engine and gives information about the engine oil condition. Engine oil deterioration will be judged by the criteria such as the neutralization number (TAN and TBN), kinematic viscosity, water contents, and carbon residue. According to the results of oil condition analysis, the oil change interval can be determined.

Engine oil filters may assist the additives to delay the time of oil replacement. Usually vehicles are equipped with full-flow filters. Full-flow filters are needed to capture manufacturing and wear metal debris from the rotating engine parts. Filters do not plug (creating high restriction) during normal operation and the recommended service intervals. The full-flow oil filter removes the larger debris from the oil that can cause abrasive engine wear. Typical full-flow oil filters have micron ratings of approximately 30 µm [2]. This porosity is required to ensure that enough oil reaches the engine to provide the required lubrication. Bypass filters are designed to remove very small particles suspended in the engine oil. A bypass filter is intended to slow the flow of oil to increase the chance of catching finer particles. Typical particles include soot, wear metals, and spent oil additives. Used in conjunction with a full-flow filter, a typical bypass device will draw approximately 5-10 % [3] of the oil flow from the lube circulation loop and return this cleaned oil back to the oil sump. Bypass oil filters are used to provide fine filtration of the oil to extend the oil drain intervals.

The aim of the research is to find a way to reduce wear in heavy-duty diesel engines and prolong the oil change intervals. It is necessary to prove that installation of the additional oil filter allows prolonging the engine oil change interval, to save the properties of engine oil and to reduce expenses on transport service and maintenance.

Materials and methods

Two Neoplan buses (N1122 Skyliner model, 2006) were chosen for this research from the big transport fleet in Riga. These buses are used in regular long-distance routes, annual run approximately 200000 km. According to the technical demands of the manufacturer of the buses oil must correspond to the MAN standard M3277 [4]. Both engines were filled with the same engine oil Q8 T860 SAE 10W-40. Information about the test vehicles is shown in Table 1. Typical inspection data of the engine oil [5] are shown in Table 2.

Table 1

Characteristics of vehicles

Designation	A	B
Engine	MAN D2876 LOH03 Euro III	MAN D2876 LOH20 Euro III
Engine power, KW	338	353
Engine torque, Nm	2100 by 900-1300 $1\cdot min^{-1}$	2300 by 1000-1400 $1\cdot min^{-1}$
Fuel system	Inline high pressure fuel pump	Common Rail
Volume of engine oil, l	33	33
Oil specification	MAN M3277	MAN M3277
Average fuel consumption	28	27.8

For this research the engines were equipped with additional bypass oil filters – patented Trabold filters. Additional oil filters were built as standalone units and joined to the oil pressure switch of the engines by a T-distribution head and oil return was made through the oil inlet pipe stub (see Fig. 1). These filters have micron ratings less than 1 µm. The manufacturer of these filters recommends changing the oil filter cartridge periodically. During this research the filter cartridges were changed every 40000 km.

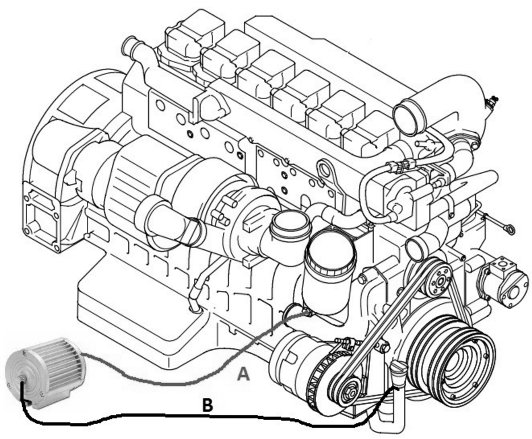

Fig. 1. **Connection of bypass oil filter:** A – feeding pipe; B – oil return pipe

Oil samples were taken every 40000 km, starting from run 80000 km. The samples were taken in the time period from December 2012 till January 2013. Oil sampling is a critical component of a high-quality and effective oil analysis, that is why the probes were taken in the same way disconnecting the feeding pipe before the additional filter. The samples were taken during typical working conditions: while the engine is running and the fluid is hot. The samples were sent to the laboratory and chemical analyses of the engine oil were done, a detailed report was generated and revealed the true condition of the oil.

In the analysis the main attention was paid to the changes of the properties of engine oil, degradation of additive compounds, also to various pollutants of engine oil and products of wear of the engine parts. The measured parameters:

- maintenance of products of wear ($mg \cdot kg^{-1}$) – lead, aluminum, chrome, iron, copper, tin, nickel, molybdenum;
- maintenance of additive compounds (%) – calcium, magnesium, zinc, phosphorus, barium, sulphur;
- maintenance of pollutants – silicon, sodium, water (%), ethylene glycol;
- oil condition, fluid properties – viscosity at 40 ºC, viscosity at 100 ºC, viscosity index, fuel dilution (% mass), Total Base Number (TBN);

Table 2

Typical inspection data of the engine oil [5]

Parameter	Units	Inspection Data
Densitty, 15 ºC	$kg \cdot m^{-3}$	871
Kinematic Viscosity, 40 ºC	$mm^2 \cdot s^{-1}$	96
Kinematic Viscosity, 100 ºC	$mm^2 \cdot s^{-1}$	14.4
Flash point	ºC	220
Total Base Number (TBN)	$mg\ KOH \cdot g^{-1}$	12.5
Sulphated Ash	% mass	1.6

To make conclusions about the results information about the limits on oil analysis tests was generalized in Table 3.

Table 3

Limits on oil analysis tests [6]

Oil Analysis Test	Caution	Critical	Shell Limits
Fuel	1.50 %	5 %	no data
Glycol	200 ppm	400 ppm	no data
Soot	2 %	5 %	no data
Viscosity	+5 %	+10 %	±20 %
Zinc	-15 %	-30 %	no data
Calcium	-10 %	-20 %	no data
TBN	-50 %	-75 %	2 mg KOH min
Water	100-300 ppm	above 300 ppm	0.10 % by vol.
Metals			**Shell Limits**
Iron (Fe)	100-200 ppm	above 200 ppm	3-150 ppm
Silicon (Si)	10-30 ppm	above 30 ppm	1-15 ppm
Chromium (Cr)	10-30 ppm	above 30 ppm	0-20 ppm
Lead (Pb)	40-100 ppm	above 100 ppm	3-50 ppm
Aluminum (Al)	10-30 ppm	above 30 ppm	2-20 ppm
Cooper (Cu)	10-50 ppm	above 50 ppm	5-65 ppm

Results and discussion

During this research 3 oil samples were taken from vehicle A and 4 oil samples were taken from vehicle B. Oil drain for vehicle A was made at 160000 km run, but for vehicle B – 200000 km. The manufacturer's recommendation for the oil change interval is 80000 km [4], but especially for this research the oil drain period was prolonged. The results of oil analysis are generalized in Table 4 and Table 5.

Oil consumption $l \cdot (1000\ km)^{-1}$ before bypass filter installation for vehicle A was $0.3\ l \cdot (1000\ km)^{-1}$, and $0.19\ l \cdot (1000\ km)^{-1}$ km for vehicle B. During this research the oil drain period was prolonged and oil consumption for vehicle A became $0.375\ l \cdot (1000\ km)^{-1}$ and $0.259\ l \cdot (1000\ km)^{-1}$. Oil consumption from 0.25 to 0.5 % of the actual fuel consumption is considered normal [4], so for the test vehicles oil consumption 0.7 to $1.4\ l \cdot (1000\ km)^{-1}$ is considered normal.

When the components of the engine wear, they generate debris in the form of small particles. The lubricant is usually the first recipient of this wear debris because of its close proximity to the frictional surfaces where the debris was formed. An increase in the concentration of elements such as iron, copper, chromium, tin, aluminum suggests that abnormal wear is occurring. Monitoring and analyzing the generated debris enables to detect and evaluate abnormal conditions such that effective engine maintenance decisions can be made. Contamination generated internally in the engine promotes premature lubricant failure. Oil analysis helps find the origins of contaminants in the oil.

Table 4

Oil analysis results, vehicle A

Fluid Age (run , km)	84000 km	123162 km	160521 km
Oil condition			
Kinematic Viscosity 40º C, $mm^2 \cdot s^{-1}$	78.1	80.6	82.6
Kinematic Viscosity 100º C, $mm^2 \cdot s^{-1}$	12.7	12.9	13.1
Water, %	<0.1	<0.1	<0.1
Soot, %	0.9	1.2	1.2
TBN, mg $KOH \cdot g^{-1}$	11.75	11.72	11.7
Fuel, %	<1	<1	1.48
Contamination and wear metals			
Na, ppm	6	4	2
K, ppm	1	1	1
Si, ppm	12	13	14
Al, ppm	6	3	5
Sn, pp,	1	2	2
Pb, ppm	2	2	2
Cu, ppm	2	1	2
Fe, ppm	44	50	56
Cr, ppm	3	4	6
Mo, ppm	150	142	145
Ni, ppm	1	1	1
Mn, ppm	1	2	2
Ti, ppm	<1	<1	<1
V, ppm	<1	<1	<1
Li, ppm	<1	<1	1
Additives			
B, ppm	75	67	65
Ba, ppm	1	<1	<1
Ca, ppm	4217	4285	4319
Mg, ppm	9	10	12
P, ppm	1318	1122	1120
S, ppm	5362	6204	6073
Zn	1625	1520	1528

Viscosity affects the engine operation, energy losses, and the oil film thickness in bearings, cylinders, valves, cams, gearing and other frictional zones. The rate of viscosity change from oil oxidative degradation depends on the presence of pro-oxidation stressing agents that are in the oil [7]. Viscosity can increase for several reasons: oxidation, thermal failure, water contamination, soot loading. The viscosity change does not exceed the limits.

The base number trend is steadily downward as the oil reserve alkalinity is depleted by the progressive neutralization of acids from combustion and base oil oxidative. A rapid change in BN may be caused by one or more of the following [3]:

- burning high-sulfur fuel;
- abnormal fuel dilution;
- poor combustion;

- excessive blowby;
- severe oxidation;
- overextended drain interval;
- glycol contamination.

The TBN change does not exceed the limits, but the level of engine oil in the test engines periodically replenished with the portion of fresh engine oil. That is why the level of additives in the samples was approximately the same. Concentration of wear metals also does not exceed the limits despite the significant increase in the oil drain interval.

Soot enters engine oil from combustion blow by. Excessive amounts occur when oil drains are overextended, air cleaners are plugged or overfueling conditions occur. Soot concentrations in the range of 2-5 % are typically flagged as abnormal. According to the results of the tests concentration of soot and fuel in the oil samples is better for vehicle B with the common rail fuel system, but in both cases does not exceed the limits.

Table 5

Oil analysis results, vehicle B

Fluid Age (run , km)	72500	118384	159537	200849
Oil condition				
Kinematic Viscosity 40 ºC, $mm^2 \cdot s^{-1}$	80.2	84.5	90.0	89.2
Kinematic Viscosity 100 ºC, $mm^2 \cdot s^{-1}$	12.6	13	13.5	13.74
Water, %	<0.1	<0.1	<0.1	<0.1
Soot, %	0.1	0.1	0.3	0.4
TBN, mg $KOH \cdot g^{-1}$	12.33	11.64	10.69	11.3
Fuel, %	<1	<1	<1	<1
Contamination and wear metals				
Na, ppm	1	3	4	4
K, ppm	1	2	3	1
Si, ppm	9	14	15	16
Al, ppm	9	7	6	7
Sn, pp,	<1	1	1	1
Pb, ppm	5	2	3	5
Cu, ppm	4	4	5	8
Fe, ppm	21	40	49	60
Cr, ppm	1	2	2	2
Mo, ppm	123	147	155	155
Ni, ppm	<1	1	1	1
Mn, ppm	1	1	2	2
Ti, ppm	<1	<1	<1	<1
V, ppm	<1	<1	1	1
Li, ppm	<1	<1	<1	<1
Additives				
B, ppm	54	45	39	34
Ba, ppm	3	3	3	3
Ca, ppm	3301	4189	4520	4385
Mg, ppm	12	14	17	16
P, ppm	1035	1113	1157	1149
S, ppm	4524	6093	6242	5906
Zn	1212	1524	1625	1583

Conclusions

During this experiment the manufacturer’s recommended oil drain interval for the test vehicles was increased more than twice. According to the results of chemical analysis of probes the main parameters of the engine oil do not exceed the limits.

Oil analysis tests help determine the right oil change interval. But the sampling procedure is a very important thing to ensure good data density and minimum data disturbance in oil samplings.

A bypass additional filter helps remove very small particles suspended in the engine oil. It helps reduce engine wear. The oil drain interval can be extended, if the additional oil filter is installed. But this interval should not be overextended, that is why it is important to follow the recommendations of the manufacturer.

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