

5 LUBRICATING OIL COMPOSITION WITH RENEWABLE BASE OIL, HAVING LOW SULFUR AND
SULFATED ASH CONTENT AND CONTAINING MOLYBDENUM AND BORON COMPOUNDS

FIELD OF THE INVENTION

A lubricating oil composition containing a renewable base oil comprising hydrocarbon mixtures and a lubricant additive having a sulfur content of up to about 0.4 wt.% and a sulphated ash content of up to about 0.5 wt. %. Method of improving engine
10 performance with lubricant oil composition containing renewable base oil comprising hydrocarbon mixtures and a lubricant additive having a sulfur content of up to about 0.4 wt.% and a sulphated ash content of up to about 0.5 wt. %, have been developed which possess unique compositional characteristics and which demonstrates improvement of fuel economy retention, turbocharger efficiency retention, peak torque retention, peak power retention,
15 reduction in the exhaust manifold temperature, and reducing oil usage over the life of the lubricant when used to lubricate various types of internal combustion engines.

BACKGROUND OF THE INVENTION

In efforts to reduce global warming, emission regulations of the automobile industries are becoming tighter year after year. Because of these regulations, the automobile industry is
20 looking for options to improve fuel economy (FE).

Because fuel economy derived from the advanced lubricants comes at a smaller cost than redesigning hardware, it is increasingly seen as an attractive route to efficiency improvement. OEMs are looking for higher vehicle efficiency and have also started looking for methods to retain vehicle efficiency. Hence, retention of fuel economy throughout the
25 useful life of a lubricant is becoming an important criterion. During automotive engine operation, lubricant deteriorates due to its oxidative and thermal degradation. Oxidative and thermal degradation can deteriorate lubricating properties such as viscosity, oxidative resistance, wear resistance, etc. This degradation can result in premature failure of critical engine components and loss of fuel economy.

30 Base stocks are commonly used to produce various lubricants, including lubricating oils for internal combustion engines, turbines, compressors, hydraulic systems, etc. They are also used as process oils, white oils, and heat transfer fluids. Finished lubricants generally consist of two components, base oils, and additives.

Base oil, which could be one or a mixture of base stocks, is the principal constituent
35 in these finished lubricants and contributes significantly to their characteristics, such as

- 5 viscosity and viscosity index, volatility, stability, and low-temperature performance. In general, a few base stocks are used to manufacture a wide variety of finished lubricants by varying the mixtures of individual base stocks and individual additives.

A method of improving engine fuel efficiency with a lubricant composition containing fatty acid esters is outlined in U.S. 9,885,004.

- 10 The American Petroleum Institute (API) categorizes base stocks in five groups based on their saturated hydrocarbon content, sulfur level, and viscosity index (Table 1 below). Group I, II, and III base stocks are mostly derived from crude oil via extensive processing, such as solvent refining for Group I, and hydroprocessing for Group II and Group III. Certain Group III base stocks can also be produced from synthetic hydrocarbon liquids via a
15 Gas-to-Liquids (GTL) process, and are obtained from natural gas, coal, or other fossil resources. Group IV base stocks, the polyalphaolefins (PAO), are produced by oligomerization of alpha olefins, such as 1-decene. Group V base stocks include everything that does not belong to Groups I – IV, such as naphthenic base stocks, polyalkylene glycols (PAG), and esters. Most of the feedstocks for large-scale base stock manufacturing are non-
20 renewable.

Table 1. API Base Oil Classification (API 1509 Appendix E)

API Group	Viscosity Index (ASTM D2270)	Saturates by ASTM D2007	Sulphur, %	Description
I	80 – 120	< 90%	>.03%	Conventional (solvent refining)
II	80 – 120	≥ 90%	≤ .03%	Hydroprocessing
III	≥ 120	≥ 90%	≤ .03%	Severe Hydroprocessing
IV				PolyAlphaOlefins (PAO)
V				All other base stocks not included above e.g. esters

- Automotive engine oils are by far the largest market for base stocks. The automotive industry has been placing more stringent performance specifications on engine oils due to
25 requirements for lower emissions, long drain intervals, and better fuel economy. Specifically, automotive OEMs (original equipment manufacturers) have been pushing for the adoption of lower viscosity engine oils such as 0W-20 to 0W-8, to lower friction losses and achieve fuel

5 economy improvement. Base Oils with a lower Noack Volatility in an engine oil allows the formulation to retain the designed viscosity for longer operation time allowing for increased fuel economy retention and longer drain intervals is discussed in US6300291. Group I and Group II's usage in 0W-xx engine oils are highly limited because formulations blended with them cannot meet the performance specifications for 0W-xx engine oils, leading to increased
10 demands for Group III and Group IV base stocks.

Group III base stocks are mostly manufactured from vacuum gas oils (VGOs) through hydrocracking and catalytic dewaxing (e.g. hydroisomerization). Group III base stocks can also be manufactured by catalytic dewaxing of slack waxes originating from solvent refining, or by catalytic dewaxing of waxes originating from Fischer-Tropsch synthesis from natural
15 gas or coal-based raw materials also known as Gas to Liquids base oils (GTL).

Manufacturing processes of Group III base stocks from VGOs is discussed in U.S. Patent Nos. 5,993,644 and 6,974,535. Their boiling point distributions are typically broader when compared to PAOs of the same viscosity, causing them to have higher volatility than PAOs. Additionally, Group III base stocks typically have higher cold crank viscosity (i.e.,
20 dynamic viscosity according to ASTM D5293, CCS) than Group IV base stocks at equivalent temperatures and viscosities.

GTL base stock processing is described in U.S. Patent Nos. 6,420,618 and 7,282,134, as well as U.S. Patent Application Publication 2008/0156697. For example, the latter publication describes a process for preparing base stocks from a Fischer-Tropsch synthesis
25 product, the fractions of which with proper boiling ranges are subjected to hydroisomerization to produce GTL base stocks.

Such structures and properties of GTL base stocks are described, for example, in U.S. Patent Nos. 6,090,989 and 7,083,713, as well as U.S. Patent Application Publication 2005/0077208. In U.S. Patent Application Publication 2005/0077208, lubricant base stocks
30 with optimized branching are described, which have alkyl branches concentrated toward the center of the molecules to improve the base stocks' cold flow properties. Nevertheless, pour points for GTL base stocks are typically higher than PAO or other synthetic hydrocarbon base stocks.

A further concern with GTL base stocks is the severely limited commercial supply, a
35 result of the prohibitively large capital requirements for a new GTL manufacturing facility. Access to low-cost natural gas is also required to profitably produce GTL base stocks. Furthermore, as GTL base stocks are typically distilled from an isomerized oil with a wide

5 boiling point distribution, the process results in a relatively low yield to the base stock with a desired viscosity when compared to that of a typical PAO process. Due to these economic and yield constraints, there is currently only a single manufacturing plant of group III+ GTL base stocks, exposing formulations that use GTL to supply chain and price fluctuation risks.

10 Polyalphaolefins (PAOs), or Group IV base oils, are produced by the polymerization of alpha-olefins in the presence of a Friedel Crafts catalyst such as $AlCl_3$, BF_3 , or BF_3 complexes. For example, 1-octene, 1-decene, and 1-dodecene have been used to manufacture PAOs that have a wide range of viscosities, varying from low molecular weight and low viscosity of about 2 cSt at 100°C, to high molecular weight, viscous materials with viscosities exceeding 100 cSt at 100°C. The polymerization reaction is typically conducted in the
15 absence of hydrogen; the lubricant range products are thereafter polished or hydrogenated to reduce the residual unsaturation. Processes to produce PAO based lubricants are disclosed, for example, in U.S. Patent Nos. 3,382,291; 4,172,855; 3,742,082; 3,780,128; 3,149,178; 4,956,122; 5,082,986; 7,456,329; 7,544,850; and U.S. Patent Application Publication 2014/0323665.

20 Prior efforts to prepare various PAOs that can meet the increasingly stringent performance requirements of modern lubricants and automotive engine oil particularly have favored low viscosity polyalphaolefin base stocks derived from 1-decene, alone, or in some blend with other mineral oils. However, the polyalphaolefins derived from 1-decene can be prohibitively expensive due to its limited supply. Attempts to overcome the availability
25 constraint of 1-decene have led to the production of PAOs from C8 through C12 mixed alpha-olefin feeds, lowering the amount of 1-decene that is needed to impart the properties. However, they still do not completely remove the requirement for providing 1-decene as the predominate olefin feedstock due to performance concerns.

30 Similarly, previous efforts to use linear alpha-olefins in the C14 – C20 range made polyalphaolefins with unacceptably high pour points, which are unsuitable for use in a variety of lubricants, including 0W engine oils.

Therefore, there remains a need for a lubricant composition having properties within commercially acceptable ranges, for example, for use in automotive and other applications, with such properties including one or more of viscosity, Noack volatility, and low-
35 temperature cold-cranking viscosity. Furthermore, there remains a need for lubricant compositions having improved properties and methods of manufacture thereof, where the

5 base stock compositions have reduced amounts of 1-decene incorporated therein, and may even preferably eliminate the use of 1-decene in the manufacture thereof.

In addition to the technical demands for the automotive industry, environmental awareness and regulations are driving manufacturers to use renewable feedstocks and raw materials in the production of base stocks and lubricants. It is known that esters and some
10 Group III hydrocarbon base stocks (US9862906B2) of renewable and biological origin have been used in applications such as refrigeration compressor lubricants, hydraulic oils, and metalworking fluids, and more recently in automotive and industrial lubricants (US20170240832A1). Common biological sources for hydrocarbons are natural oils, which can be derived from plant sources such as canola oil, castor oil, sunflower seed oil, rapeseed
15 oil, peanut oil, soybean oil, and tall oil, or palm oil. Other commercial sources of hydrocarbons include engineered microorganisms such as algae or yeast.

Due to the increasing demand for high performing lubricant base stocks, there is a continuing need for improved hydrocarbon mixtures. The industry requires these hydrocarbon mixtures to have superior Noack Volatility and low-temperature viscometric
20 properties that can meet stricter engine oil requirements, preferably from renewable sources.

Exhaust after-treatment devices are installed on the internal combustion engines to enable them to comply with emission regulations. Combustion byproducts of fuels and lubricants can reduce the useful life of exhaust after-treatment devices. In particular, sulfur coming from fuel and lubricant, phosphorus coming from a lubricant, and sulphated ash
25 coming from lubricants are known to reduce the durability of exhaust after-treatment devices. Hence to prolong the life of exhaust after-treatment devices certain types of lubricants are being developed with reducing amount of sulphated ash, phosphorus, and sulfur, commonly known as low SAPS formulations.

U.S. Patent No. 9,523,061 B2 discloses a lubricating oil composition having a sulfur
30 content of up to about 0.4 wt.% and sulphated ash of up to about 0.5 wt.%.

SUMMARY OF THE INVENTION

An embodiment of the invention is a lubricating oil composition containing a renewable base oil comprising hydrocarbon mixtures and a lubricant additive package having
35 a sulfur content of up to about 0.4 wt.% and a sulphated ash content of up to about 0.5 wt. %.

5 Another embodiment is a method of improving engine performance with lubricant oil composition containing renewable base oil comprising hydrocarbon mixtures and a lubricant additive package having a sulfur content of up to about 0.4 wt.% and a sulphated ash content of up to about 0.5 wt. %, have been developed which possess characteristics demonstrating improvement of fuel economy retention, turbocharger efficiency retention, peak torque
10 retention, peak power retention, reduction in the exhaust manifold temperature, and reducing oil usage over the life of the lubricant when used to lubricate various types of internal combustion engines.

DESCRIPTION OF THE INVENTION

In accordance with one embodiment of the invention, a lubricant composition
15 possessing a "renewable base oil", as defined herein as a base oil with a saturated hydrocarbon mixture having greater than 80% of the molecules with an even carbon number according to FIMS, with the mixture exhibiting a branching characteristic of $BP/BI \geq -0.6037$ (Internal alkyl branching per molecule) + 2.0, and when the hydrocarbon mixture is analyzed by carbon NMR as a whole, has on average at least 0.3 to 1.5 5+ methyl branches per
20 molecule. One way to synthesize the hydrocarbon mixture disclosed herein is through the oligomerization of C14 -C20 alpha or internal-olefins, followed by hydroisomerization of the oligomers.

Using C14 -C20 olefins would ease the demand for high-price 1-decene and other crude oil or synthetic gas-based olefins as feedstocks and making available alternate sources
25 of olefin feedstocks such as those derived from C14 - C20 alcohols. The hydrocarbon compositions are derived from one or more olefin co-monomers, where said olefin comonomers are oligomerized to dimers, trimers, and higher oligomers. The oligomers are then subjected to hydroisomerization. The resulting hydrocarbon mixtures have excellent pour point, volatility and viscosity characteristics, and additive solubility properties.

30 An embodiment of the invention is a lubricating oil composition having a renewable base oil described above blended with an additive package wherein sulfur content of up to about 0.4 wt.% and a sulphated ash content up to about 0.5 wt.% as determined by the ASTM D874 is provided which comprises (1) oil-soluble boron containing compound which contributes from about 400 ppm and no more than 2000 ppm of boron based upon the total
35 mass of the composition and preferably from about 600 ppm and no more than 1000 ppm of Boron based upon the total mass of the composition; (2) oil-soluble molybdenum containing

5 compound which contributes from about 700 ppm of molybdenum and no more than 1500 ppm of molybdenum based upon the total mass of the composition wherein lubricating oil composition has ratio of sulfur to molybdenum of about 0.5:1 to less than and equal to 4:1; further wherein the lubricating oil composition is substantially free of zinc dialkyl dihiophosphate compounds. Representative additive packages are described in U.S.
10 9,523,061 B2, herein incorporated by reference.

In accordance with another embodiment of the invention, a lubricant oil composition having renewable base oil with low sulphated ash additive package where kinematic viscosity at 100°C is less than or equal to 12.5 cSt, based on ASTM D445; high-temperature high shear viscosity is less than or equal to 3.2 cP, based on ASTM D5481; low-temperature cold
15 cranking viscosity at -30°C is less than or equal to 6600 mPa.s, based on ASTM D5293; SAE viscosity grade less than or equal to 5W-30, based on SAE J300, for example, 5W-20, 0W-30, 0W-20, 0W-16, 0W-12 and 0W-8.

“Conventional lubricant” is herein defined as lubricant compositions not employing the “renewable base oil” described herein.

20 “Internal combustion engine” as defined herein comprises diesel engines, including heavy and medium duty diesel engines.

A further embodiment of the invention is a method where supplying the lubricant composition to a heavy-duty diesel engine results in an improvement in fuel efficiency retention, wherein the internal combustion engine includes a diesel engine. Particularly,
25 resulting in improving fuel economy retention by at least 0.2% and a method for improving fuel efficiency retention in internal combustion engines preferably by more than 0.4% better than a conventional lubricant of equal viscosity.

An additional embodiment is a method of reducing oil usage by supplying the lubricant composition to a heavy-duty diesel engine. Total oil usage has described the
30 lubricant consumed during the engine operation and lubricant drained due to loss in its effectiveness to lubricate internal combustion engines. The reduction in oil usage is at least 30% and preferably by more than 50% as measured against a conventional lubricant of equal viscosity.

The method of supplying the lubricating composition as described herein to a heavy-
35 duty diesel engine results in extending oil drain interval that is at least 50% preferably by more than 60 % as compared to a conventional lubricant of equal viscosity.

5 The method of supplying the lubricant composition to a medium-duty diesel engine as described herein, provides additional improvements comprising:

- (a) loss of fuel economy relative to the start of the test that is less than 5% and preferably no more than 3% compared to a conventional lubricant of equal viscosity;
- (b) total oil consumption that is below 7500 grams preferably below 6500 grams than a conventional lubricant of equal viscosity;
- (c) loss of peak torque relative to the start of the test that is no more than 50 Nm and preferably no more than 30 Nm compared to a conventional lubricant of equal viscosity;
- (d) loss of peak power relative to the start of the test that is no more than 20KW and preferably no more than 10KW compared to conventional lubricant of equal viscosity;
- (e) loss of turbocharger efficiency by less than 10% and preferably no more than 5%.
- (f) an increase in exhaust manifold temperature relative to the start of the test is below 50°C and preferably no more than 20°C compared to a conventional lubricant of equal viscosity.

20 **EXAMPLE**

A comparative lubricating oil composition 1 was prepared by blending mineral base oil group II with an additive package with a conventional level of sulphated ash. A comparative lubricating oil composition 2 was prepared by blending mineral base oil group II with an additive package with a low level of sulphated ash. A comparative lubricating oil composition 3 was prepared by blending renewable base oil with an additive package with a conventional level of sulphated ash. A lubricant of the invention was prepared by blending renewable base oil with an additive package with a low level of sulphated ash. Viscosity modifier and trimming fluid were added to obtain kinematic viscosity at 100°C between 7.25-8.25 cSt and high-temperature high shear viscosity at 150°C between 2.5 to 2.6 cP. Table 1 shows the detailed composition of lubricating oils and the respective additive concentrations.

	Examples	Comparativ e lubricant 1	Comparativ e lubricant 2	Comparativ e lubricant 3	Lubricant of Invention
1	Mineral Base Oil (group II) (%)	75.13	69.38	--	--
2	Renewable base oil (%)	--	--	80.80	77.10
3	Conventional sulphated ash Additive Package (%)	19.00	--	19.00	--
4	Low sulphated ash Additive Package (%)	--	22.7	--	22.7
5	Pour Pt. Depressant (%)	0.2	0.2	0.2	0.2
6	Trim Fluid (%)	5.67	7.72	--	--
7	Total (%)	100	100	100	100
	Additives				
8	Phosphorus, ppm	750	0	750	0
9	Zinc, ppm	850	0	850	0
10	Boron, ppm,	400	800	400	800
11	Molybdenum, ppm	120	1100	120	1100
12	Sulfur, wt%	0.2	0.16	0.2	0.16
13	Sulphated Ash, %	0.9	0.4	0.9	0.4

5

Table 1 Lubricating oils composition

Testing in a heavy duty diesel engine:

It is well known that during automotive engine operation, lubricant deteriorates due to its oxidative and thermal degradation. Oxidative and thermal degradation can deteriorate lubricating properties such as viscosity, oxidative resistance, wear resistance, etc. This can result in premature failure of critical engine components and an increase in fuel consumption or loss of fuel economy. To measure fuel economy loss and oil usage a Volvo D-13/MP8 13L, in-line six-cylinder, four-cycle diesel engine equipped with a turbocharger and exhaust gas recirculation, running on ultra-low sulfur diesel fuel was used.

Determination of fuel economy retention (%)

To measure the fuel economy retention due to the degradation of lubricating properties during engine operation, a test was designed that sequentially measures Fuel efficiency – Oil degradation (aging) – Fuel efficiency. This cycle was repeated until engine operation exhibited a significant loss of fuel economy.

5 The fuel efficiency cycle was run as a discrete mode cycle utilizing EPA Supplemental Emission Testing (SET) procedure. The SET cycle consists of a 13-mode steady-state engine dynamometer test. In each mode, the engine runs at a specific speed and load combination for the prescribed time and move to the next mode. A 13-mode cycle was repeated seven times and the average fuel consumption of seven cycles was measured in
10 grams/minutes. The oil degradation (aging) cycle was operated at engine speed 1500 rpm, fuel flow 68 kg/h, oil gallery temperature 130° C. Detailed description of degradation (aging) test condition is described in ASTM D8048.

 The fuel economy retention test was started by measuring the fuel consumption of engine oil filled with undegraded lubricant using the 13-mode SET cycle as mentioned above.
15 This is followed by the oil degradation (aging) cycle as per the engine test conditions mentioned above. The oil degradation cycle was operated for 90 hours. This is followed by the fuel efficiency cycle to measure a change in fuel consumption due to oil degraded for 90 hours. Fuel Efficiency – Oil degradation – Fuel Efficiency cycle was repeated for 360 hours with equal 90 hours segments.

20 Furthermore, fuel consumption values for undegraded lubricant and aged lubricant (at each 90 hours segment) were used to compute the change in the fuel economy (%). Furthermore, average fuel economy change after 360 hours of engine operation was calculated by averaging the average values of fuel economy change calculated at 90, 180, 270, and 360 hours. A summary of the average fuel economy change of comparative
25 examples and lubricant of the invention is provided in table 2.

Determination of oil drain interval capability

 A lubricating oil that operates under the test conditions described in the ASTM D8048 for 360 hours is likely to worsen its lubricating properties and may no longer be usable for normal engine operation. Once lubricating oil degrades to such condition then it should be
30 drained out of the engine and replaced with fresh lubricating oil. The rejection limit of a lubricant varies depending on the applications and severity of applications. One skilled in the art knows that determining a unified rejection point or condemning limit for all lubricating oils is difficult. Hence, for the given experiment, a loss of 0.5 % fuel efficiency was used as a point of lubricating oil replacement. Hence oil drain interval (ODI) is defined as a period of
35 engine operation in hours from the start of the test to the replacement of a new lubricating oil. If any lubricating oil did not show a loss of 0.5 % fuel economy by 360 hours of engine operation, then the test cycle was extended until it showed deterioration in fuel economy of

- 5 0.5 %. A summary of the oil drain interval after a loss of 0.5% fuel economy by comparative examples and lubricant of the invention is provided in the table 2.

Determination of oil usage

The total lubricant used during the engine operation was calculated by adding the initial charge of fresh lubricant and lubricant consumed during the engine operation. The initial charge of the lubricant was 21.5 kg. Lubricant consumed during the engine operation was calculated by monitoring the lubricant level in the engine over the duration of the test by periodically checking an oil level indicator, and by translating that observed lubricant level into an amount of oil present in the engine. This amount was then corrected for the lubricant sample that was removed from the engine and by the amount of fresh lubricant that was added to maintain the lubricant level every 30 hours. The total lubricant consumed after 360 hours was calculated by adding oil consumed in grams at every 30 hours interval. A summary of the total oil consumed after 360 hours of engine operation by comparative examples and lubricant of the invention is provided in Table 2.

Examples	Comparative Example 1	Comparative Example 2	Comparative Example 3	Lubricant of the Invention
1 Avg. FE Change after 360 hrs (%)	-0.493	-0.389	-0.591	-0.012
2 ODI after 0.5 % FE Loss (Hours)	230	280	200	450
3 Oil consumed after 360 hrs (kg)	16.031	8.889	10.686	5.790
4 Improvement in fuel economy retention relative to example 1 (%)	--	0.104	-0.098	0.481
5 Improvement in the ODI relative to example 1 (%)	--	21.73	-13.05	95.65
6 Reduction in the oil usage relative to example 1 (%)	--	44.55	33.34	63.88

20 Table 2 Composition of lubricants and respective change in fuel economy (%) and oil drain interval

Table 2 summarized the average fuel economy change (%) after lubricants aged for 360 hours, oil drain intervals when engine lost 0.5 % fuel economy and total oil consumed after 360 hours. As shown in Table 2, the lubricant of the invention shows the lowest change in the fuel economy loss after it degraded for 360 hours compared to comparative examples. Also, the lubricant of the invention shows the longest oil drain interval compared to

5 comparative examples. Furthermore, the lubricant of the invention shows the lowest amount of oil consumed after 360 hours of engine operation compared to comparative examples.

Comparative example 1 was formulated with conventional base oil and conventional lubricant additive package. Comparative example 2 was formulated by replacing conventional lubricant additive package with low sulphated ash additive package and kept
10 conventional base oil as it is. Comparative examples 3 was formulated by replacing conventional base oil with renewable base oil and kept conventional lubricant additive package as it is. Lubricant of the invention was formulated with low sulphated ash additive package and renewable base oil. In order to determine their relative performance, comparative example 2, 3, and lubricant of the invention were compared to the example 1.
15 For example, example 2 and 3 show improvement in the fuel economy retention relative to example 1 by 0.104 % and -0.098%. While lubricant of the invention shows improvement in the fuel economy retention relative to example 1 by 0.481%. These results demonstrated that combining renewable base oil and low sulphated ash additive package would improve fuel economy retention by more than the sum of the individual contributions of low sulphated ash
20 additive package (example 2) and renewable base oil (example 3). This indicates the synergy between renewable base oil and low sulphated ash additive technology. Similarly, improvement in the ODI after engine lost 0.5% fuel economy also indicates synergy between renewable base oil and low sulphated ash additive technology.

Testing in medium-duty diesel engine:

25 The crankcase of an internal combustion engine accumulates gases and oil mist, known as blow-by. Crankcase blow-by gases can be a source of particulate emissions, and also contribute to increased oil consumption, deposit build-up on pistons and liners, and reduce engine cleanliness. Some IC engines use closed crankcase ventilation (CCV) systems to reduce the harmful impact of blow-by gases on the environment. US EPA has listed CCV
30 as a retrofit system to reduce PM by about 10%. In the CCV system, blow-by gases are recirculated via an oil-mist separator (OMS) to the engine air intake system to return to the combustion process. The OMS works on the principle of coalescence to separate the oil from the gases. As blow-by gases pass through the medium (filters or baffles), small oil droplets collect on the medium's surface. These oil droplets coalesce and collect at the bottom of the
35 OMS and return to the oil sump. The clean blow-by gases get mixed with the engine intake air and enter the combustion chamber via the turbocharger. Although the modern CCV

5 system is highly efficient, the CCV system's filtration efficiency is limited to keep crankcase pressure under limits. Hence some of the oil particles (mist) escape from the CCV system and accumulate on the turbocharger compressor and form a soot-containing deposit in the compressor. This phenomenon causes significant deterioration of turbocharger efficiency and, consequently, higher fuel consumption and reduction in the engine specific power. To
10 measure the reduction in the turbocharger efficiency and consequent reduction in the peak torque and fuel economy and increase in the exhaust temperature, a Ford 6.7 liter V8 engine was used. The Ford 6.7 liter V8 engine is equipped with direct injection common rail, exhaust gas recirculation, and variable geometry turbocharger and is rated at 1050 lb-ft peak torque at 1800 rpm.

15 In order to determine change in the turbocharger efficiency and subsequent change in the fuel consumption, peak power, peak torque, exhaust gas temperatures, and oil consumption, the test was conducted in three steps.

Step 1: Fuel consumption and power sweep at the start of the test

At the start of the test, the engine was operated to run power sweep and fuel
20 efficiency tests. The fuel efficiency cycle ran as a discrete mode cycle utilizing EPA Supplemental Emission Testing (SET) procedure. The SET cycle consists of a 13-mode steady-state engine dynamometer test. In each mode, the engine ran at a specific speed and load combination for the prescribed time and moved to the next mode. The engine repeated the 13-mode cycle four times and measured the average fuel consumption of four cycles in
25 grams/minute.

A power sweep measures the diesel engine's torque (Nm) and power (KW) produced at different engine speeds (rpm). Engine torque and power values were generated by
30 connecting a dynamometer to the diesel engine and measuring the torque and power the engine can produce at different speeds. For the given experiment, the engine is run at 1000 rpm and the maximum torque value is recorded. This is followed by measuring a maximum torque at next higher speed. In the given experiment, torque and power values were recorded for engine speeds between 1000 and 3000 rpm in 100 RPM increments. Ford. 6.7 L engine is rated to produce peak torque at 1800 rpm and peak power at 2800 rpm. Peak torque and peak power values were used to compare comparative example 1 and lubricant of the invention.

35 *Step 2: Turbocharger efficiency*

- 5 The engine is operated at nearly full load conditions to target 3% soot generation at the end of 100 hours. During this stage, temperature (T_{in}) and pressure (P_{in}) going into the inlet of the turbocharger compressor and temperature (T_{out}) and pressure (P_{out}) coming out of the compressor going to the charge air cooler were also measured. These temperatures and pressures were used to calculate turbocharger efficiency using the following equation.

$$\eta_c = \frac{T_{in} \left[\left(\frac{P_{out}}{P_{in}} \right)^{\frac{(K-1)}{K}} - 1 \right]}{(T_{out} - T_{in})}$$

- 10 Cylinder outlet (exhaust) temperature was also measured. This stage was considered complete once the cylinder outlet temperature exceeded 800 °C (rated temperature of turbocharger). The loss of turbocharger efficiency was noted at this point. The point where this rise in exhaust temperature occurred for the Comparative Example 1 lubricant, defined the test duration for the test on the Lubricant of the Invention.

- 15 *Step 3: Fuel consumption and power sweep step at the end of the test*

Power sweep and fuel efficiency tests were conducted for Comparative Example 1 lubricant, as mentioned in step 1. A subsequent test on the Lubricant of the Invention was conducted as per the procedure mentioned in steps 1-3.

- 20 Change in the turbocharger efficiency was measured throughout the test. To calculate the loss in the turbocharger efficiency, the measured turbocharger efficiency was compared to the turbocharger efficiency at the start of the test, when all engine components were clean. Table 3 summarizes the loss of turbocharger efficiency relative to the start of test for Comparative Example 1 and Lubricant of the Invention.

- 25 Similarly, fuel efficiency change (%), loss of peak power, loss of peak torque, increase in the exhaust gas temperatures were calculated by subtracting values of each parameter at the end of the test and at the start of the test. Table 3 summarizes these parameters for Comparative Example 1 and Lubricant of the Invention.

Examples		Comparative Example 1	Lubricant of the Invention
1	Loss in the turbocharger efficiency relative to SOT (%)	13.5	0.6
2	Loss in fuel economy relative to SOT (%)	7.33	1.12
3	Loss in the peak torque relative to SOT (N.m)	78.7	9.4
4	Loss in the peak power relative to SOT (KW)	25.3	5.1
5	Increase in exhaust manifold temp. relative to SOT (°C)	55.4	4.3
6	Total oil consumption at EOT (grams)	7757.62	6335

5

As shown in Table 3, the Lubricant of the Invention shows a smaller turbocharger efficiency loss, smaller fuel economy loss, smaller peak power loss, smaller peak torque loss, smaller increase in the exhaust gas temperature and less total oil consumption than Comparative Example 1.

10

What is claimed is

1. A lubricating composition that comprises
 - a. a mixture of base oil having at least 25 wt. % renewable base oil comprising a hydrocarbon mixture in which (a) the percentage of molecules with even carbon number is $\geq 80\%$ according to FIMS (b) the $BP/BI \geq -0.6037$ (Internal alkyl branching per molecule) + 2.0 (c) on average there are 0.3 to 1.5 5+ methyl per molecule; and
 - b. an additive composition having a sulfur content of up to about 0.4 wt. % and a sulfated ash content of up to about 0.5 wt. %, as determined by ASTM D874 and comprising of (a,) at least one oil-soluble of dispersed oil stable boron containing compound having from 400 ppm to no more than 2000 ppm of boron, based upon the total mass of composition (b) at least one oil-soluble or dispersed oil stable molybdenum containing compound having from about 700 ppm of molybdenum to no more than 1500 ppm of molybdenum, based upon the total mass of composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 0.5:1 to less than or equal to about 4:1, and further wherein the lubricating oil composition is substantially free of zinc dialkyl dithiophosphate, wherein the total additive concentration ranges from about 20 % to 30% and base oils mixtures from about 70 % to 80%.
2. The lubricating composition of claim 1, wherein lubricating high-temperature high shear viscosity is less than or equal to 3.2 cP, based on ASTM D5481.
3. The lubricating composition of claim 1, wherein lubricating kinematic viscosity at 100°C is less than or equal to 12.5 cSt, based on ASTM D445.
4. The lubricating composition of claim 1, wherein lubricating low temperature cold cranking viscosity at -25°C is less than or equal to 7000 mPa.s, based on ASTM D5293.
5. The lubricating composition of claim 1, wherein low temperature pumping viscosity is less than or equal to 60,000 mPa.S at 30°C without any yield stress, based on ASTM D4686.

6. A method of improving fuel economy retention, extending oil drain interval and reducing oil consumption of an internal combustion engine with lubricants that comprises
 - a. a mixture of base oil having at least 25 wt. % renewable base oil comprising a hydrocarbon mixture in which (a) the percentage of molecules with even carbon number is $\geq 80\%$ according to FIMS (b) the BP/BI ≥ -0.6037 (Internal alkyl branching per molecule) + 2.0 (c) on average there are 0.3 to 1.5 5+ methyl per molecule; and an
 - b. additive composition having a sulfur content of up to about 0.4 wt. % and sulfated ash content of up to about 0.5 wt. %, as determined by ASTM D874 and comprising of (a,) at least one oil-soluble or dispersed oil stable boron containing compound having from 400 ppm to no more than 2000 ppm of boron, based upon the total mass of composition (b) at least one oil-soluble or dispersed oil stable molybdenum containing compound having from about 700 ppm of molybdenum to no more than 1500 ppm of molybdenum, based upon the total mass of composition; wherein the lubricating oil composition has a ratio of sulfur to molybdenum of about 0.5:1 to less than or equal to about 4:1, and further wherein the lubricating oil composition is substantially free of zinc dialkyl dithiophosphate.
7. The method of claim 6, wherein fuel economy retention is improved by more than 0.2%.
8. The method of claim 7, wherein the internal combustion engine is a heavy duty diesel engine.
9. The method of claim 6, wherein the oil drain interval is extended by more than 30%.
10. The method of claim 9, wherein the internal combustion engine is a heavy-duty diesel engine.
11. The method of claim 6, wherein the oil usage is reduced by more than 50%.
12. The method of claim 11, wherein the internal combustion engine is a heavy duty diesel engine.

13. A method for reducing the loss of fuel economy in internal combustion engines to no more than 6% by supplying the composition of claim 1.
14. The method of claim 13, wherein the internal combustion engine is a medium duty diesel engine.
15. The method for reducing loss of peak torque in internal combustion engines to no more than 70 Nm by supplying the composition of claim 1.
16. The method of claim 15, wherein the internal combustion engine is a medium duty diesel engine.
17. A method for reducing loss of peak power in internal combustion engines to no more than 20KW by supplying the composition of claim 1.
18. The method of claim 17, wherein the internal combustion engine is a medium duty diesel engine.
19. A method for reducing rise in the exhaust manifold temperature in internal combustion engines to no more than 50 °C by supplying the composition of claim 1.
20. The method of claim 19, wherein the internal combustion engine is a medium duty diesel engine.
21. A method for reducing oil usage in internal combustion engines to no more than 7500 grams by supplying the composition of claim 1.
22. The method of claim 21, wherein the internal combustion engine is a medium duty diesel engine.