

5 LUBRICATING OIL COMPOSITION PROVIDING WEAR PROTECTION AT LOW VISCOSITY

FIELD OF THE INVENTION

The disclosed technology relates to lubricants for internal combustion engines,
10 particularly those for spark ignition engines.

BACKGROUND OF THE INVENTION

Engine oil is blended with various additives to satisfy various performance requirements. One well known way to increase fuel economy is to decrease the viscosity of the lubricating oil. However, this approach is now reaching the limits of current equipment capabilities and specifications. At a given viscosity, it is well known that adding organic or organometallic friction modifiers reduces the surface friction of the lubricating oil and allows for better fuel economy. However, these additives often bring with them detrimental effects such as increased deposit formation, seals impacts, or they out-compete the anti-wear components for limited surface sites, thereby not allowing the formation of an anti-wear film, causing increased wear.

In order to improve lubricant fuel economy performance, reduction of viscosity is typically the best path (i.e., high temperature high- shear (HTHS) viscosity). HTHS is the measure of a lubricant's viscosity under severe engine conditions. Under high temperatures and high stress conditions viscosity index improver degradation can occur. As this happens, the viscosity of the oil decreases which may lead to increased engine wear.

Therefore, despite the advances in lubricant oil formulation technology, there remains a need for an engine oil lubricant that effectively improves fuel economy while providing superior anti-wear performance.

RELATED ART

WO2015041891 discloses a method for reducing aqueous phase separation of an emulsion comprising ethanol-based fuel and a lubricating oil comprising molybdenum ester amide complex and a dispersant polyalkyl (meth) acrylate.

US 6303548 discloses an SAE 0W-40 lubricant comprises the base oil and a mixture of polymethacrylate and olefin copolymer or hydrogenated diene VI improvers.

WO2014136643 discloses a polymethacrylate having a mass average molecular weight of 30,000 to 600,000 inclusive and (B) an olefin copolymer having a 95% loss temperature of

5 500°C or lower as measured by a differential thermal analysis and a shear stability index (SSI) of 40 or less to a lubricant oil base oil.

US 20090270294 discloses a mixture of at least two polymers having a difference of permanent shear stability index (PSSI).

10 EP1436369 discloses a biodegradable lubricant that is at least 60% biodegradable and has a gelation index of about 12 or less can be formulated using a trans-esterified triglyceride base oil together with a synthetic ester. A combination of an ester viscosity index improver and an olefin copolymer viscosity index improver also can be added.

15 US20170088789 discloses a lubricant composition containing a (meth)-acrylate-containing polymer comprising a multiplicity of arms containing at least 20 carbon atoms, said arms being attached to a multivalent organic moiety; and an ethylene/olefin copolymer having a weight average molecular weight of about 10,000 to about 250,000.

SUMMARY OF THE INVENTION

20 In one aspect, the present disclosure provides a lubricating engine oil composition having a HTHS viscosity at 150°C in a range of about 1.3 to about 2.9 mPa·s, comprising:

- a) a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100°C in a range of 1.5 to 6.0 mm²/s;
- b) a dispersant polymethacrylate (DPMA) VII having a Mw of from 200,000 g/mol to 450,000 g/mol;
- 25 c) a non-dispersant ethylene-based olefin copolymer viscosity index improver having a Mw of from 50,000 g/mol to 150,000 g/mol and a total ethylene content of about 50 wt % to about 70 wt %;
- d) from about 50 to about 300 ppm of molybdenum from a molybdenum containing compound; and
- 30 e) a minor amount of a salicylate detergent.

In another aspect, the present disclosure provides method for improving friction and reducing wear in an internal combustion engine comprising lubricating said engine with a lubricating oil composition having a HTHS viscosity at 150°C in a range of about 1.3 to about 2.9 mPa·s, comprising:

- 35 a) a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100°C in a range of 1.5 to 6.0 mm²/s;

- 5 b) a dispersant polymethacrylate (DPMA) VII having a Mw of from 200,000 g/mol to 450,000 g/mol;
- c) a non-dispersant ethylene-based olefin copolymer viscosity index improver having a Mw of from 50,000 g/mol to 150,000 g/mol and a total ethylene content of about 50 wt % to about 70 wt %;
- 10 d) from about 50 to about 300 ppm of molybdenum from a molybdenum containing compound; and
- e) a minor amount of a salicylate detergent.

DETAILED DESCRIPTION OF THE INVENTION

To facilitate the understanding of the subject matter disclosed herein, a number of
15 terms, abbreviations or other shorthand as used herein are defined below. Any term, abbreviation or shorthand not defined is understood to have the ordinary meaning used by a skilled artisan contemporaneous with the submission of this application.

Definitions

In this specification, the following words and expressions, if and when used, have the
20 meanings given below.

A “major amount” means in excess of 50 weight % of a composition.

A “minor amount” means less than 50 weight % of a composition, expressed in respect of the stated additive and in respect of the total mass of all the additives present in the composition, reckoned as active ingredient of the additive or additives.

25 “Active ingredients” or “actives” refers to additive material that is not diluent or solvent.

All percentages reported are weight % on an active ingredient basis (i.e., without regard to carrier or diluent oil) unless otherwise stated.

The abbreviation “ppm” means parts per million by weight, based on the total weight
30 of the lubricating oil composition.

High temperature high shear (HTHS) viscosity at 150°C was determined in accordance with ASTM D4683.

Kinematic viscosity at 100°C (KV₁₀₀) was determined in accordance with ASTM D445.

5 Metal – The term “metal” refers to alkali metals, alkaline earth metals, or mixtures thereof.

 Throughout the specification and claims the expression oil soluble or dispersible is used. By oil soluble or dispersible is meant that an amount needed to provide the desired level of activity or performance can be incorporated by being dissolved, dispersed or suspended in
10 an oil of lubricating viscosity. Usually, this means that at least about 0.001% by weight of the material can be incorporated in a lubricating oil composition. For a further discussion of the terms oil soluble and dispersible, particularly “stably dispersible”, see U.S. Pat. No. 4,320,019 which is expressly incorporated herein by reference for relevant teachings in this regard.

 The term “sulfated ash” as used herein refers to the non-combustible residue resulting
15 from detergents and metallic additives in lubricating oil. Sulfated ash may be determined using ASTM Test D874.

 The term “Total Base Number” or “TBN” as used herein refers to the amount of base equivalent to milligrams of KOH in one gram of sample. Thus, higher TBN numbers reflect more alkaline products, and therefore a greater alkalinity. TBN was determined using ASTM
20 D 2896 test.

 Boron, calcium, magnesium, molybdenum, phosphorus, sulfur, and zinc contents were determined in accordance with ASTM D5185.

 Nitrogen content was determined in accordance with ASTM D4629.

 All ASTM standards referred to herein are the most current versions as of the filing
25 date of the present application.

 Olefins – The term “olefins” refers to a class of unsaturated aliphatic hydrocarbons having one or more carbon-carbon double bonds, obtained by a number of processes. Those containing one double bond are called mono-alkenes, and those with two double bonds are called dienes, alkyldienes, or diolefins. Alpha olefins are particularly reactive because the
30 double bond is between the first and second carbons. Examples are 1-octene and 1-octadecene, which are used as the starting point for medium-biodegradable surfactants. Linear and branched olefins are also included in the definition of olefins.

 Normal Alpha Olefins – The term “Normal Alpha Olefins” “refers to olefins which are straight chain, non-branched hydrocarbons with carbon-carbon double bond present in the
35 alpha or primary position of the hydrocarbon chain.

 Isomerized Normal Alpha Olefin. The term “Isomerized Normal Alpha Olefin” as used herein refers to an alpha olefin that has been subjected to isomerization conditions which results in an alteration of the distribution of the olefin species present and/or the introduction of

5 branching along the alkyl chain. The isomerized olefin product may be obtained by isomerizing a linear alpha olefin containing from about 10 to about 40 carbon atoms, preferably from about 20 to about 28 carbon atoms, and preferably from about 20 to about 24 carbon atoms.

C₁₀₋₄₀ Normal Alpha Olefins – This term defines a fraction of normal alpha olefins wherein the carbon numbers below 10 have been removed by distillation or other fractionation
10 methods.

Unless otherwise specified, all percentages are in weight percent.

While the disclosure is susceptible to various modifications and alternative forms, specific embodiments thereof are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the disclosure to the
15 particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the appended claims.

Note that not all of the activities described in the general description or the examples are required, that a portion of a specific activity may not be required, and that one or more
20 further activities may be performed in addition to those described. Still further, the order in which activities are listed is not necessarily the order in which they are performed.

Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more
25 pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

The specification and illustrations of the embodiments described herein are intended to provide a general understanding of the structure of the various embodiments.

As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,”
30 “having,” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of features is not necessarily limited only to those features but may include other features not expressly listed or other features that are inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive-or and not to an exclusive-or. For
35 example, a condition A or B is satisfied by any one of the following: A is true (or present) and

- 5 B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

The use of “a” or “an” is employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the embodiments of the disclosure. This description should be read to include one or at least one
10 and the singular also includes the plural, or vice versa, unless it is clear that it is meant otherwise. The term “averaged,” when referring to a value, is intended to mean an average, a geometric mean, or a median value. Group numbers corresponding to columns within the Periodic Table of the elements use the “New Notation” convention as seen in the CRC Handbook of Chemistry and Physics, 81st Edition (2000-2001).

- 15 Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. The materials, methods, and examples are illustrative only and not intended to be limiting. To the extent not described herein, many details regarding specific materials and processing acts are conventional and may be found in textbooks and other sources within the
20 lubricants as well as the oil and gas industries.

The specification and illustrations are not intended to serve as an exhaustive and comprehensive description of all the elements and features of formulations, compositions, apparatus and systems that use the structures or methods described herein. Separate embodiments may also be provided in combination in a single embodiment, and conversely,
25 various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any sub-combination. Further, reference to values stated in ranges includes each and every value within that range. Many other embodiments may be apparent to skilled artisans only after reading this specification. Other embodiments may be used and derived from the disclosure, such that a structural substitution, logical substitution, or another
30 change may be made without departing from the scope of the disclosure. Accordingly, the disclosure is to be regarded as illustrative rather than restrictive.

Oil of Lubricating viscosity/Base Oil Component

- The oil of lubricating viscosity (sometimes referred to as “base stock” or “base oil”) is the primary liquid constituent of a lubricant, into which additives and possibly other oils are
35 blended, for example to produce a final lubricant (or lubricant composition). A base oil is useful for making concentrates as well as for making lubricating oil compositions therefrom, and may be selected from natural and synthetic lubricating oils and combinations thereof.

5 Natural oils include animal and vegetable oils, liquid petroleum oils and hydrorefined, solvent-treated mineral lubricating oils of the paraffinic, naphthenic and mixed paraffinic-naphthenic types. Oils of lubricating viscosity derived from coal or shale are also useful base oils.

Synthetic lubricating oils include hydrocarbon oils such as polymerized and
10 interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes); alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)benzenes; polyphenols (e.g., biphenyls, terphenyls, alkylated polyphenols); and alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogues and
15 homologues thereof.

Another suitable class of synthetic lubricating oils comprises the esters of dicarboxylic acids (e.g., malonic acid, alkyl malonic acids, alkenyl malonic acids, succinic acid, alkyl succinic acids and alkenyl succinic acids, maleic acid, fumaric acid, azelaic acid, suberic acid, sebacic acid, adipic acid, linoleic acid dimer, phthalic acid) with a variety of alcohols (e.g.,
20 butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol). Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-*n*-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the complex ester formed by reacting one mole of sebacic acid with
25 two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid.

Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols, and polyol ethers such as neopentyl glycol, trimethylolpropane, pentaerythritol, dipentaerythritol and tripentaerythritol.

The base oil may be derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-
30 Tropsch synthesized hydrocarbons are made from synthesis gas containing H₂ and CO using a Fischer-Tropsch catalyst. Such hydrocarbons typically require further processing in order to be useful as the base oil. For example, the hydrocarbons may be hydroisomerized; hydrocracked and hydroisomerized; dewaxed; or hydroisomerized and dewaxed; using processes known to those skilled in the art.

35 Unrefined, refined and re-refined oils can be used in the present lubricating oil composition. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. For example, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from distillation or ester oil obtained directly from

5 an esterification process and used without further treatment would be unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques, such as distillation, solvent extraction, acid or base extraction, filtration and percolation are known to those skilled in the art. Re-refined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such re-refined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques for approval of spent additive and oil breakdown products.

Hence, the base oil which may be used to make the present lubricating oil composition may be selected from any of the base oils in Groups I-V as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines (API Publication 1509). Such base oil groups are summarized in Table 1 below:

TABLE 1

Group ^(a)	Base Oil Properties		
	Saturates ^(b) , wt. %	Sulfur ^(c) , wt. %	Viscosity Index ^(d)
Group I	<90 and/or	>0.03	80 to <120
Group II	≥90	≤0.03	80 to <120
Group III	≥90	≤0.03	≥120
Group IV	Polyalphaolefins (PAOs)		
Group V	All other base stocks not included in Groups I, II, III or IV		

^(a) Groups I-III are mineral oil base stocks.

20 ^(b) Determined in accordance with ASTM D2007.

^(c) Determined in accordance with ASTM D2622, ASTM D3120, ASTM D4294 or ASTM D4927.

^(d) Determined in accordance with ASTM D2270.

25 Base oils suitable for use herein are any of the variety corresponding to API Group II, Group III, Group IV, and Group V oils and combinations thereof, preferably the Group III to Group V oils due to their exceptional volatility, stability, viscometric and cleanliness features.

The base oil constitutes the major component of the present lubricating oil composition and is present in an amount ranging from greater than 50 to 99 wt. % (e.g., 70 to 95 wt. %, or 85 to 95 wt. %).

5 The base oil may be selected from any of the synthetic or natural oils typically used as crankcase lubricating oils for spark-ignited internal combustion engines. The base oil typically has a kinematic viscosity at 100°C in a range of 1.5 to 6 mm²/s. In the case where the kinematic viscosity at 100°C of the lubricating base oil exceeds 6 mm²/s, low temperature viscosity properties may be reduced, and sufficient fuel efficiency may not be obtained. At a kinematic
10 viscosity of 1.5 mm²/s or less, formation of an oil film in a lubrication place is insufficient; for this reason, lubrication is inferior, and the evaporation loss of the lubricating oil composition may be increased.

 Preferably, the base oil has a viscosity index of at least 90 (e.g., at least 95, at least 105, at least 110, at least 115, or at least 120). If the viscosity index is less than 90, not only viscosity-
15 temperature properties, heat and oxidation stability, and anti-volatilization are reduced, but also the coefficient of friction tends to be increased; and resistance against wear tends to be reduced.

 In one embodiment, the lubricating oil composition is a multi-grade oil. In another embodiment, the multi-grade oil is a viscosity grade SAE 0W-XX oil, wherein XX is any one of 8, 10, 12, 16, and 20.

20 The lubricating oil composition has a high temperature shear (HTHS) viscosity at 150°C of 2.9 mPa·s or less (e.g., 1.0 to 2.9 mPa·s, or 1.3 to 2.9 mPa·s) of 2.6 mPa·s or less (e.g., 1.0 to 2.6 mPa·s, or 1.3 to 2.6 mPa·s) of 2.3 mPa·s or less (e.g., 1.0 to 2.3 mPa·s, or 1.3 to 2.3 mPa·s), such as 2.0 mPa·s or less (e.g., 1.0 to 2.0 mPa·s, or 1.3 to 2.3 mPa·s), or even 1.7 mPa·s or less (e.g., 1.0 to 1.7 mPa·s, or 1.3 to 1.7 mPa·s).

25 The lubricating oil composition has a viscosity index of at least 135 (e.g., 135 to 400, or 135 to 250), at least 150 (e.g., 150 to 400, 150 to 250), at least 165 (e.g., 165 to 400, or 165 to 250), at least 190 (e.g., 190 to 400, or 190 to 250), or at least 200 (e.g., 200 to 400, or 200 to 250). If the viscosity index of the lubricating oil composition is less than 135, it may be difficult to improve fuel efficiency while maintaining the HTHS viscosity at 150°C. If the viscosity
30 index of the lubricating oil composition exceeds 400, evaporation properties may be reduced, and deficits due to insufficient solubility of the additive and matching properties with a seal material may be caused.

 The lubricating oil composition has a kinematic viscosity at 100°C in a range of 3 to 12 mm²/s (e.g., 3 to 8.2 mm²/s, 3.5 to 8.2 mm²/s, or 4 to 8.2 mm²/s).

35 In general, the level of sulfur in the lubricating oil compositions of the present invention is less than or equal to about 0.7 wt. %, based on the total weight of the lubricating oil

5 composition, e.g., a level of sulfur of about 0.01 wt. % to about 0.70 wt. %, 0.01 to 0.6 wt.%, 0.01 to 0.5 wt.%, 0.01 to 0.4 wt.%, 0.01 to 0.3 wt.%, 0.01 to 0.2 wt.%, 0.01 wt. % to 0.10 wt.

5 %. In one embodiment, the level of sulfur in the lubricating oil compositions of the present invention is less than or equal to about 0.60 wt. %, less than or equal to about 0.50 wt. %, less than or equal to about 0.40 wt. %, less than or equal to about 0.30 wt. %, less than or equal to about 0.20 wt. %, less than or equal to about 0.10 wt. % based on the total weight of the lubricating oil composition.

10 In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.12 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.12 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.11 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.11 wt. %.

15 In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.10 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.10 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.09 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.09 wt. %.

20 In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.08 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.08 wt. %. In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.07 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.07 wt. %.

25 In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.05 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.05 wt. %.

30 In one embodiment, the levels of phosphorus in the lubricating oil compositions of the present invention is less than or equal to about 0.04 wt. %, based on the total weight of the lubricating oil composition, e.g., a level of phosphorus of about 0.01 wt. % to about 0.04 wt. %.

35 In one embodiment, the level of sulfated ash produced by the lubricating oil compositions of the present invention is less than or equal to about 1.60 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 1.60 wt. % as determined by ASTM D 874. In one embodiment, the level of sulfated ash produced by the lubricating oil compositions of the present invention is less than or equal to about 1.00 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 1.00 wt. % as determined by ASTM D 874. In one embodiment, the level of sulfated ash produced by the

- 5 lubricating oil compositions of the present invention is less than or equal to about 0.80 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 0.80 wt. % as determined by ASTM D 874. In one embodiment, the level of sulfated ash produced by the lubricating oil compositions of the present invention is less than or equal to about 0.60 wt. % as determined by ASTM D 874, e.g., a level of sulfated ash of from about 0.10 to about 10 0.60 wt. % as determined by ASTM D 874.

Suitably, the present lubricating oil composition may have a total base number (TBN) of 4 to 15 mg KOH/g (e.g., 5 to 12 mg KOH/g, 6 to 12 mg KOH/g, or 8 to 12 mg KOH/g).

Viscosity modifier

- Viscosity modifiers (VM) or viscosity index improvers (VIIs) may be used in the 15 lubricant to impart high and low temperature operability. VM may be used to impart that sole function or may be multifunctional. Multifunctional viscosity modifiers also provide additional functionality for dispersant function. Examples of Viscosity modifiers and dispersant viscosity modifiers are polymethacrylates, polyacrylates, polyolefins, styrene-maleic ester copolymer and similar polymeric substances including homopolymers, copolymers and graft copolymers.

- 20 In one embodiment, the VIIs can be present in the lubricating oil composition from 0.001 to 10 wt.% based on the lubricating oil composition. In other embodiments, the VIIs can be present from 0.01 to 8 wt.%, from 0.01 to 5 wt.%, from 0.01 to 4 wt.%, from 0.01 to 3 wt.%, from 0.01 to 2.5 wt.%, from 0.1 to 2.5 wt.% the lubricating oil composition.

- Particularly useful in this disclosure is the combination of a dispersant 25 polymethacrylate VII and an ethylene based non-dispersant VII.

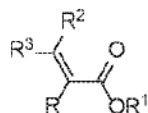
Dispersant Polymethacrylate (DPMA) VII

- In one embodiment, the dispersant PMA has a weight average molecular weight of from 200,000 g/mol to 450,000 g/mol, from 200,000 g/mol to 400,000 g/mol, from 200,000 g/mol 30 to 350,000 g/mol, or from 200,000 g/mol to 300,000 g/mol.

- The dispersant polymethacrylate (DPMA) viscosity index modifier used in the present invention can be described as follows, and as set forth in WO 2013/182581, the disclosure of which is incorporated herein. Compounds within this definition would include Viscoplex® viscosity index improvers 6-054, 6-565, 6-850, 6-950 and 6-954, all available from Evonik 35 RohMax Additives GmbH of Darmstadt, Germany.

The polyalkyl(meth)acrylate(s) comprise monomer units of:

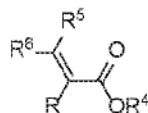
- 5 (a) 0 to 40% by weight of one or more ethylenically unsaturated ester compounds of the formula (I):



Formula I

- wherein R is hydrogen or methyl, R¹ is a saturated or unsaturated linear or branched alkyl radical having 1 to 5 carbon atoms or a saturated or unsaturated cycloalkyl group having 3 to 5 carbon atoms, R² and R³ are each independently hydrogen or a group of the formula -COOR' wherein R' is hydrogen or a saturated or unsaturated linear or branched alkyl group having 1 to 5 carbon atoms;

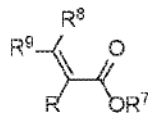
- 15 (b) 10 to 98% by weight, preferably 20 to 95% by weight, of one or more ethylenically unsaturated ester compounds of the formula (II)



Formula II

- wherein R is hydrogen or methyl, R⁴ is a saturated or unsaturated linear or branched alkyl radical having 6 to 15 carbon atoms or a saturated or unsaturated cycloalkyl group having 6 to 15 carbon atoms, R⁵ and R⁶ are each independently hydrogen or a group of the formula -COOR'' in which R'' is hydrogen or a saturated or unsaturated linear or branched alkyl group having 6 to 15 carbon atoms;

- (c) 0 to 30% by weight, preferably 5 to 20% by weight, of one or more ethylenically unsaturated ester compounds of the formula (III):



Formula III

- wherein R is hydrogen or methyl, R⁷ is a saturated or unsaturated linear or branched alkyl radical having 16 to 40 preferably 16 to 30, carbon atoms or a cycloalkyl group having 16 to 40, preferably 16 to 30, carbon atoms, R⁸ and R⁹ are each independently hydrogen or a group of the formula -COOR''' in which R''' is hydrogen or a saturated or unsaturated linear or branched alkyl group having 16 to 40, preferably 16 to 30, carbon atoms;

- (d) 0 to 30% by weight of vinyl monomers;

- (e) 2 to 10% by weight of at least one N-dispersant monomer.

5 The DPMA used in the present invention is believed to contain about 1 to 10 wt.% methyl methacrylate monomer, about 0.5 to 3 wt. % N-vinyl pyrrolidone as the nitrogen-containing monomer, and the balance longer chain alkyl methacrylate monomers, in particular, lauryl methacrylate, and has a MW of from 200,000 to 250,000. It has an SSI of from about 40 to about 50.

10 **Non-Dispersant Ethylene-based Olefin Copolymer (OCP) VII**

 In one embodiment, the non-dispersant ethylene-based olefin copolymer VII has a weight average molecular weight of from 50,000 g/mol to about 150,000 g/mol, from about 60,000 g/mol to about 120,000 g/mol, or from about 70,000 g/mol to about 110,000 g/mol.

15 The ethylene-based viscosity index modifier used in the present invention can be described as follows, and as set forth in US20130203640, the disclosure of which is incorporated herein.

 In one embodiment, the ethylene-based VII is an ethylene propylene copolymer.

 In one embodiment, the polymer compositions typically contain about 30 wt % to about 20 70 wt % of the first ethylene- α -olefin copolymer (a) and about 70 wt % to about 30 wt % of the second ethylene- α -olefin copolymer (b) based upon the total amount of (a) and (b) in the composition. In another embodiment, the polymer compositions typically contain about 40 wt % to about 60 wt % of the first ethylene- α -olefin copolymer (a) and about 60 wt % to about 40 wt % of the second ethylene- α -olefin copolymer (b) based upon the total amount of (a) and (b) 25 in the composition. In a particular embodiment, the polymer composition contains about 50 to about 54 wt % of the first ethylene- α -olefin copolymer (a) and about 46 to about 50 wt % of the second ethylene- α -olefin copolymer (b) based upon the total amount of (a) and (b) in the composition.

 The weight average molecular weight of the first ethylene- α -olefin copolymer in one 30 embodiment is typically about 60,000 g/mol to about 120,000 g/mol. In another embodiment, the weight average molecular weight of the first ethylene- α -olefin copolymer is typically about 70,000 g/mol to about 110,000 g/mol. The weight average molecular weight of the second ethylene- α -olefin copolymer in one embodiment is typically about 60,000 g/mol to about 120,000 g/mol. In another embodiment, the weight average molecular weight of the second 35 ethylene- α -olefin copolymer is typically about 70,000 g/mol to about 110,000 g/mol. The weight average molecular weight of the composition of the first ethylene- α -olefin copolymer

5 and second ethylene- α -olefin copolymer in one embodiment is typically about 60,000 g/mol to about 120,000 g/mol. In another embodiment, the weight average molecular weight of the composition of the first ethylene- α -olefin copolymer and second ethylene- α -olefin copolymer is typically about 70,000 g/mol to about 110,000 g/mol. In a still further embodiment, the weight average molecular weight of the composition of the first ethylene- α -olefin copolymer
10 and second ethylene- α -olefin copolymer is typically about 80,000 to about 100,000 g/mol. The molecular weight distribution of each of the ethylene- α -olefin copolymers is typically less than about 2.5, and more typically about 2.1 to about 2.4. The polymer distribution as determined by GPC is typically unimodal.

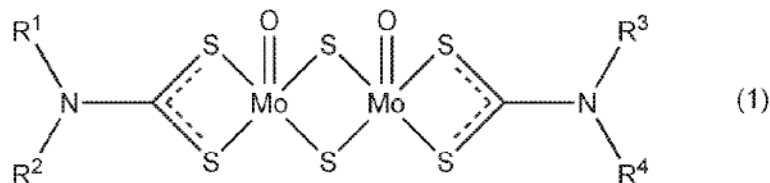
In one embodiment, the polymer compositions typically have a total ethylene content
15 of about 40 wt. % to about 70 wt. %, or about 50 wt. % to about 70 wt. %. In another embodiment, the polymer compositions typically have a total ethylene content of about 55 wt. % to about 65 wt. %. In other embodiments, the polymer composition has a total ethylene content of about 57 wt. % to about 63 wt. %.

20 **Organomolybdenum Compound**

The organomolybdenum compound contains at least molybdenum, carbon and hydrogen atoms, but may also contain sulfur, phosphorus, nitrogen and/or oxygen atoms. Suitable organomolybdenum compounds include molybdenum dithiocarbamates, molybdenum dithiophosphates, and various organic molybdenum complexes such as
25 molybdenum carboxylates, molybdenum esters, molybdenum amines, molybdenum amides, which can be obtained by reacting molybdenum oxide or ammonium molybdates with fats, glycerides or fatty acids, or fatty acid derivatives (e.g., esters, amines, amides). The term "fatty" means a carbon chain having 10 to 22 carbon atoms, typically a straight carbon chain.

Molybdate esters prepared by methods disclosed in US 4,889,647 and US 6,806,241
30 B2 . A commercial example is MOLYVAN® 855 additive, which is manufactured by R. T. Vanderbilt Company, Inc.

Molybdenum dithiocarbamate (MoDTC) is an organomolybdenum compound represented by the following structure (1):

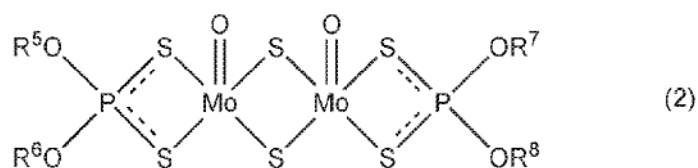


wherein R^1 , R^2 , R^3 and R^4 are independently of each other, linear or branched alkyl groups having from 4 to 18 carbon atoms (e.g., 8 to 13 carbon atoms).

Preparations of these compounds are well known in the literature and U.S. Pat. Nos. 3,356,702 and 4,098,705 are incorporated herein for reference. Commercial examples include MOLYVAN® 807, MOLYVAN® 822, and MOLYVAN® 2000, which are manufactured by R. T. Vanderbilt Company Inc., SAKURA-LUBE® 165 and SAKURA-LUBE® 515, which are manufactured by ADEKA CORPORATION and Naugalube® MolyFM which is manufactured by Chemtura Corporation.

Trinuclear molybdenum dialkyldithiocarbamates are also known in the art, as taught by U.S. Pat. Nos. 5,888,945 and 6,010,987, herein incorporated by reference. Trinuclear molybdenum compounds preferably those having the formulas $Mo_3S_4(dtc)_4$ and $Mo_3S_7(dtc)_4$ and mixtures thereof wherein *dtc* represents independently selected diorganodithiocarbamate ligands containing independently selected organo groups and wherein the ligands have a sufficient number of carbon atoms among all the organo groups of the compound's ligands are present to render the compound soluble or dispersible in the lubricating oil.

Molybdenum dithiophosphate (MoDTP) is an organomolybdenum compound represented by the following structure (2):



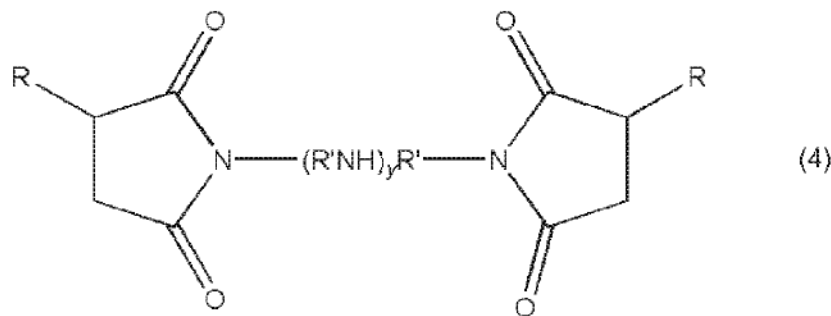
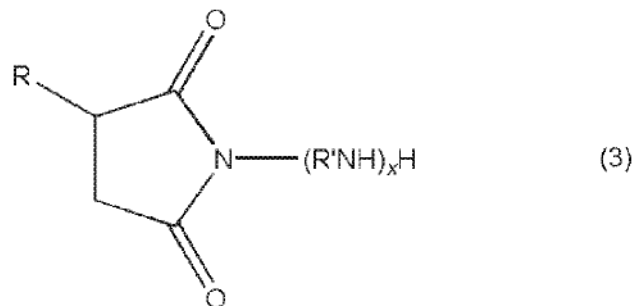
wherein R^5 , R^6 , R^7 and R^8 are independently of each other, linear or branched alkyl groups having from 4 to 18 carbon atoms (e.g., 8 to 13 carbon atoms).

Molybdenum carboxylates are described in U.S. Pat. RE 38,929, and U.S. Pat. No. 6,174,842 and thus are incorporated herein by reference. Molybdenum carboxylates can be derived from any oil soluble carboxylic acid. Typical carboxylic acids include naphthenic acid,

5 2-ethylhexanoic acid, and linolenic acid. Commercial sources of carboxylates produce from these particular acids are MOLYBDENUM NAP-ALL, MOLYBDENUM HEX-CEM, and MOLYBDENUM LIN-ALL respectively. Manufacturer of these products is OMG OM Group.

Ammonium molybdates are prepared by the acidibase reaction of acidic molybdenum source such as molybdenum trioxide, molybdic acid, and ammonium molybdate and
 10 ammonium thiomolybdates with oil-soluble amines and optionally in presence of sulfur sources such sulfur, inorganic sulfides and polysulfides, and carbons disulfide to name few. The preferred aminic compounds are polyamine dispersants that are commonly used engine oil compositions. Examples of such dispersants are succinimides and Mannich type. References to these preparations are U.S. Pat. Nos. 4,259,194, 4,259,195, 4,265,773, 4,265,843, 4,727,387,
 15 4,283,295, and 4,285,822.

In one embodiment, the molybdenum amine is a molybdenum-succinimide complex. Suitable molybdenum-succinimide complexes are described, for example, in U.S. Patent No. 8,076,275. These complexes are prepared by a process comprising reacting an acidic molybdenum compound with an alkyl or alkenyl succinimide of a polyamine of structure (3)
 20 or (4) or mixtures thereof:



5 wherein R is a C₂₄ to C₁₅₀ (e.g., C₇₀ to C₁₂₈) alkyl or alkenyl group; R' is a straight or branched-chain alkylene group having 2 to 3 carbon atoms; x is 1 to 11; and y is 1 to 10.

The molybdenum compounds used to prepare the molybdenum-succinimide complex are acidic molybdenum compounds or salts of acidic molybdenum compounds. By "acidic" is meant that the molybdenum compounds will react with a basic nitrogen compound as measured
10 by ASTM D664 or D2896. Generally, the acidic molybdenum compounds are hexavalent. Representative examples of suitable molybdenum compounds include molybdenum trioxide, molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdate and other alkaline metal molybdates and other molybdenum salts such as hydrogen salts, (e.g., hydrogen sodium molybdate), MoOCl₄, MoO₂Br₂, Mo₂O₃Cl₆, and the like.

15 The succinimides that can be used to prepare the molybdenum-succinimide complex are disclosed in numerous references and are well known in the art. Certain fundamental types of succinimides and the related materials encompassed by the term of art "succinimide" are taught in U.S. Patent Nos. 3,172,892; 3,219,666; and 3,272,746. The term "succinimide" is understood in the art to include many of the amide, imide, and amidine species which may also
20 be formed. The predominant product however is a succinimide and this term has been generally accepted as meaning the product of a reaction of an alkyl or alkenyl substituted succinic acid or anhydride with a nitrogen-containing compound. Preferred succinimides are those prepared by reacting a polyisobutenyl succinic anhydride of about 70 to 128 carbon atoms with a polyalkylene polyamine selected from triethylenetetramine, tetraethylenepentamine, and
25 mixtures thereof.

In one embodiment, the molybdenum containing compound is free of sulfur.

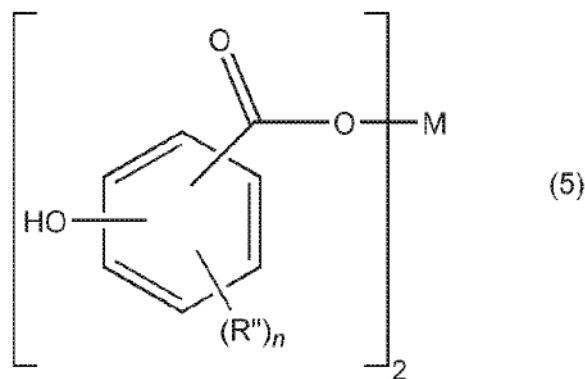
The molybdenum-succinimide complex may be post-treated with a sulfur source at a suitable pressure and a temperature not to exceed 120°C to provide a sulfurized molybdenum-succinimide complex. The sulfurization step may be carried out for a period of from about 0.5
30 to 5 hours (e.g., 0.5 to 2 hours). Suitable sources of sulfur include elemental sulfur, hydrogen sulfide, phosphorus pentasulfide, organic polysulfides of formula R₂S_x where R is hydrocarbyl (e.g., C₁ to C₁₀ alkyl) and x is at least 3, C₁ to C₁₀ mercaptans, inorganic sulfides and polysulfides, thioacetamide, and thiourea.

The molybdenum containing compound is used in an amount that provides from about
35 50 to about 300 ppm of molybdenum, about 50 to about 275 ppm, about 50 to about 250 ppm, about 50 to about 200 ppm, or about 50 to about 175 ppm by weight of molybdenum to the lubricating oil composition.

- 5 In some embodiments, the lubricating oil composition is substantially free of molybdenum containing element.

Salicylate Detergent

- Salicylates may be prepared by reacting a basic metal compound with at least one
 10 carboxylic acid and removing water from the reaction product. Detergents made from salicylic acid are one class of detergents prepared from carboxylic acids. Useful salicylates include long chain alkyl salicylates. One useful family of compositions is of the following structure (5):



- 15 wherein R'' is a C₁ to C₃₀ (e.g., C₁₃ to C₃₀) alkyl group; *n* is an integer from 1 to 4; and M is an alkaline earth metal (e.g., Ca or Mg).

- Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction (see U.S. Patent No. 3,595,791). The metal salts of the hydrocarbyl-substituted
 20 salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent such as water or alcohol.

- In one aspect of the present disclosure, the salicylate is derived from C₁₀-C₄₀ isomerized NAO and is made from an alkylphenol with an alkyl group derived from an isomerized NAO having an isomerization level (i) from about 0.10 to about 0.40, preferably from about 0.10 to
 25 about 0.35, preferably from about 0.10 to about 0.30, and more preferably from about 0.12 to about 0.30.

A typical detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the detergent is typically derived from an organic acid such as a sulfur acid,

5 carboxylic acid, phosphorous acid, phenol, or mixtures thereof. The counterion is typically an alkaline earth or alkali metal.

Salts that contain a substantially stoichiometric amount of the metal are described as neutral salts and have a total base number (TBN) of from 0 to 80 mg KOH/g. Many compositions are overbased, containing large amounts of a metal base that is achieved by
10 reacting an excess of a metal compound (e.g., a metal hydroxide or oxide) with an acidic gas (e.g., carbon dioxide). Useful detergents can be neutral, mildly overbased, or highly overbased.

It is desirable for at least some detergent used in the detergent mixture to be overbased. Overbased detergents help neutralize acidic impurities produced by the combustion process and become entrapped in the oil. Typically, the overbased material has a ratio of metallic ion
15 to anionic portion of the detergent of 1.05:1 to 50:1 (e.g., 4:1 to 25:1) on an equivalent basis. The resulting detergent is an overbased detergent that will typically have a TBN of 150 mg KOH/g or higher (e.g., 250 to 450 mg KOH/g or more). A mixture of detergents of differing TBN can be used.

Suitable detergents include metal salts of sulfonates, phenates, carboxylates,
20 phosphates, and salicylates.

Sulfonates may be prepared from sulfonic acids which are typically obtained by the sulfonation of alkyl-substituted aromatic hydrocarbons such as those obtained from the fractionation of petroleum or by the alkylation of aromatic hydrocarbons. Examples included those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl or their halogen
25 derivatives. The alkylation may be carried out in the presence of a catalyst with alkylating agents having from about 3 to more than 70 carbon atoms. The alkaryl sulfonates usually contain from about 9 to 80 or more carbon atoms (e.g., about 16 to 60 carbon atoms) per alkyl substituted aromatic moiety.

Phenates can be prepared by reacting an alkaline earth metal hydroxide or oxide (e.g.,
30 CaO, Ca(OH)₂, MgO, or Mg(OH)₂) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight or branched chain C₁ to C₃₀ (e.g., C₄ to C₂₀) alkyl groups, or mixtures thereof. Examples of suitable phenols include isobutylphenol, 2-ethylhexylphenol, nonylphenol, dodecyl phenol, and the like. It should be noted that starting alkylphenols may contain more than one alkyl substituent that are each independently straight chain or branched
35 chain. When a non-sulfurized alkylphenol is used, the sulfurized product may be obtained by methods well known in the art. These methods include heating a mixture of alkylphenol and sulfurizing agent (e.g., elemental sulfur, sulfur halides such as sulfur dichloride, and the like) and then reacting the sulfurized phenol with an alkaline earth metal base.

5

Magnesium Detergent

Preferred magnesium-containing detergents include magnesium sulfonates, magnesium phenates, and magnesium salicylates, especially magnesium sulfonates.

The magnesium-containing detergent may be used in an amount that provides at least
10 250 ppm to 1000 ppm (e.g., 250 to 1000 ppm, 250 to 800 ppm, 300 to 1000 ppm, 300 to 800 ppm, 400 to 1000 ppm, or 400 to 800 ppm) by weight of magnesium to the lubricating oil composition.

Other Lubricating Oil Additives

In addition to the additives compound described herein, the lubricating oil
15 composition can comprise additional lubricating oil additives.

The lubricating oil compositions of the present disclosure may also contain other conventional additives that can impart or improve any desirable property of the lubricating oil composition in which these additives are dispersed or dissolved. Any additive known to a person of ordinary skill in the art may be used in the lubricating oil compositions disclosed herein. Some suitable additives have been described in Mortier et al., "Chemistry and
20 Technology of Lubricants", 2nd Edition, London, Springer, (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications", New York, Marcel Dekker (2003), both of which are incorporated herein by reference. For example, the lubricating oil compositions can be blended with antioxidants, anti-wear agents, metal detergents, rust inhibitors, dehazing
25 agents, demulsifying agents, metal deactivating agents, friction modifiers, pour point depressants, antifoaming agents, co-solvents, corrosion-inhibitors, ashless dispersants, multifunctional agents, dyes, extreme pressure agents and the like and mixtures thereof. A variety of the additives are known and commercially available. These additives, or their analogous compounds, can be employed for the preparation of the lubricating oil compositions
30 of the disclosure by the usual blending procedures.

The lubricating oil composition of the present invention can contain one or more anti-wear agents that can reduce friction and excessive wear. Any anti-wear agent known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable anti-wear agents include zinc dithiophosphate, metal (e.g., Pb, Sb, Mo
35 and the like) salts of dithiophosphates, metal (e.g., Zn, Pb, Sb, Mo and the like) salts of dithiocarbamates, metal (e.g., Zn, Pb, Sb and the like) salts of fatty acids, boron compounds,

5 phosphate esters, phosphite esters, amine salts of phosphoric acid esters or thiophosphoric acid esters, reaction products of dicyclopentadiene and thiophosphoric acids and combinations thereof. The amount of the anti-wear agent may vary from about 0.01 wt. % to about 5 wt. %, from about 0.05 wt. % to about 3 wt. %, or from about 0.1 wt. % to about 1 wt. %, based on the total weight of the lubricating oil composition.

10 In certain embodiments, the anti-wear agent is or comprises a dihydrocarbyl dithiophosphate metal salt, such as zinc dialkyl dithiophosphate compounds. The metal of the dihydrocarbyl dithiophosphate metal salt may be an alkali or alkaline earth metal, or aluminum, lead, tin, molybdenum, manganese, nickel or copper. In some embodiments, the metal is zinc. In other embodiments, the alkyl group of the dihydrocarbyl dithiophosphate metal salt has from
15 about 3 to about 22 carbon atoms, from about 3 to about 18 carbon atoms, from about 3 to about 12 carbon atoms, or from about 3 to about 8 carbon atoms. In further embodiments, the alkyl group is linear or branched.

The amount of the dihydrocarbyl dithiophosphate metal salt including the zinc dialkyl dithiophosphate salts in the lubricating oil composition disclosed herein is measured by
20 its phosphorus content. In some embodiments, the phosphorus content of the lubricating oil composition disclosed herein is from about 0.01 wt. % to about 0.14 wt. %, based on the total weight of the lubricating oil composition.

The lubricating oil composition of the present invention can contain one or more friction modifiers that can lower the friction between moving parts. Any friction modifier
25 known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable friction modifiers include fatty carboxylic acids; derivatives (e.g., alcohol, esters, borated esters, amides, metal salts and the like) of fatty carboxylic acid; mono-, di- or tri-alkyl substituted phosphoric acids or phosphonic acids; derivatives (e.g., esters, amides, metal salts and the like) of mono-, di- or tri-alkyl substituted phosphoric acids
30 or phosphonic acids; mono-, di- or tri-alkyl substituted amines; mono- or di-alkyl substituted amides and combinations thereof. In some embodiments examples of friction modifiers include, but are not limited to, alkoxylated fatty amines; borated fatty epoxides; fatty phosphites, fatty epoxides, fatty amines, borated alkoxylated fatty amines, metal salts of fatty acids, fatty acid amides, glycerol esters, borated glycerol esters; and fatty imidazolines as
35 disclosed in U.S. Patent No. 6,372,696, the contents of which are incorporated by reference herein; friction modifiers obtained from a reaction product of a C₄ to C₇₅, or a C₆ to C₂₄, or a

5 C₆ to C₂₀, fatty acid ester and a nitrogen-containing compound selected from the group consisting of ammonia, and an alkanolamine and the like and mixtures thereof. The amount of the friction modifier may vary from about 0.01 wt. % to about 10 wt. %, from about 0.05 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 3 wt. %, based on the total weight of the lubricating oil composition.

10 The lubricating oil composition of the invention preferably contains an organic oxidation inhibitor in an amount of 0.01-5 wt. %, preferably 0.1-3 wt. %. The oxidation inhibitor can be a hindered phenol oxidation inhibitor or a diarylamine oxidation inhibitor. The diarylamine oxidation inhibitor is advantageous in giving a base number originating from the nitrogen atoms. The hindered phenol oxidation inhibitor is advantageous in producing no NO_x
15 gas.

Examples of the hindered phenol oxidation inhibitors include 2,6-di-*t*-butyl-*p*-cresol, 4,4'-methylenebis(2,6-di-*t*-butylphenol), 4,4'-methylenebis(6-*t*-butyl-*o*-cresol), 4,4'-isopropylidenebis(2,6-di-*t*-butylphenol), 4,4'-bis(2,6-di-*t*-butylphenol), 2,2'-methylenebis(4-methyl-6-*t*-butylphenol), 4,4'-thiobis(2-methyl-6-*t*-butylphenol), 2,2-thio-
20 diethylenebis[3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate], octyl 3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate, octadecyl 3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate, and octyl 3-(3,5,4-butyl-4-hydroxy-3-methylphenyl)propionate, and commercial products such as, but not limited to, Irganox L135® (BASF), Naugalube 531® (Chemtura), and Ethanox 376® (SI Group).

25 Examples of the diarylamine oxidation inhibitors include alkylldiphenylamine having a mixture of alkyl groups of 4 to 9 carbon atoms, *p,p'*-dioctyldiphenylamine, phenyl-naphthylamine, phenyl-naphthylamine, alkylated-naphthylamine, and alkylated phenyl-naphthylamine.

Each of the hindered phenol oxidation inhibitor and diarylamine oxidation
30 inhibitor can be employed alone or in combination. If desired, other oil soluble oxidation

In the preparation of lubricating oil formulations, it is common practice to introduce the additives in the form of 10 to 80 wt. % active ingredient concentrates in hydrocarbon oil, e.g. mineral lubricating oil, or other suitable solvent.

Usually these concentrates may be diluted with 3 to 100, e.g., 5 to 40, parts by
35 weight of lubricating oil per part by weight of the additive package in forming finished

- 5 lubricants, e.g. crankcase motor oils. The purpose of concentrates, of course, is to make the handling of the various materials less difficult and awkward as well as to facilitate solution or dispersion in the final blend.

Processes of Preparing Lubricating Oil Compositions

- 10 The lubricating oil compositions disclosed herein can be prepared by any method known to a person of ordinary skill in the art for making lubricating oils. In some embodiments, the base oil can be blended or mixed with the zirconium-containing compounds described herein. Optionally, one or more other can be added. The additives may be added to the base oil individually or simultaneously. In some embodiments, the additives are added to
15 the base oil individually in one or more additions and the additions may be in any order. In other embodiments, the additives are added to the base oil simultaneously, optionally in the form of an additive concentrate. In some embodiments, the solubilizing of the additives in the base oil may be assisted by heating the mixture to a temperature from about 25 °C to about 200 °C, from about 50 °C to about 150 °C or from about 75 °C to about 125 °C.

- 20 Any mixing or dispersing equipment known to a person of ordinary skill in the art may be used for blending, mixing or solubilizing the ingredients. The blending, mixing or solubilizing may be carried out with a blender, an agitator, a disperser, a mixer (e.g., planetary mixers and double planetary mixers), a homogenizer (e.g., Gaulin homogenizers and Rannie homogenizers), a mill (e.g., colloid mill, ball mill and sand mill) or any other mixing or
25 dispersing equipment known in the art.

Application of the Lubricating Oil Compositions

- The lubricating oil composition disclosed herein may be suitable for use as motor oils (that is, engine oils or crankcase oils), in a spark-ignited internal combustion engine,
30 particularly direct injected and boosted engines.

- The following examples are presented to exemplify embodiments of the invention but are not intended to limit the invention to the specific embodiments set forth. Unless indicated to the contrary, all parts and percentages are by weight. All numerical values are approximate. When numerical ranges are given, it should be understood that embodiments
35 outside the stated ranges may still fall within the scope of the invention. Specific details described in each example should not be construed as necessary features of the invention.

5

EXAMPLES

The following examples are intended for illustrative purposes only and do not limit in any way the scope of the present invention.

EXAMPLE 1

10 A lubricating oil composition was prepared by blending together the following components to obtain an SAE 0W-20 viscosity grade formulation:

- (a) 740 ppm, in terms of phosphorus content, of a secondary zinc dialkyldithiophosphate;
- (b) 1120 ppm, in terms of calcium content, the majority coming from an C₁₄-C₁₈ normal alpha olefin derived overbased calcium salicylate and a minor amount from a low overbased calcium sulfonate detergent;
- 15 (c) 840 ppm, in terms of magnesium of a highly overbased magnesium sulfonate detergent;
- (d) An ethylene carbonate treated and a borated succinimide dispersant;
- (e) an alkylated diphenylamine antioxidant, hindered phenol antioxidant;
- 20 (f) conventional amounts of pour point depressant,
- (g) a combination of viscosity index improvers which was 0.70 wt.% of a polymer concentrate which contains an ethylene propylene derived non-dispersant OCP (ethylene propylene based copolymer with between 55 to 65% ethylene, a weight average molecular weight of 80,000 to about 100,000 g/mol, and an SSI of about 20 to about 26) and 1.50 wt.% of polymer concentrate which contains a dispersant type PMA (1 to 10 wt.% methyl methacrylate monomer, about 0.5 to 3 wt. % N-vinyl pyrrolidone as the nitrogen-containing monomer, and the balance longer chain alkyl methacrylate monomers, in particular, lauryl methacrylate, and has a MW
- 25 of from 200,000 to 250,000. It has an SSI of from about 40 to about 50, and
- 30 (h) 0.2 wt.% of a sulfur free molybdenum in an amount to provide 160 ppm of molybdenum
- (i) foam inhibitor; and
- (j) the balance a mixture of Group III and Group IV PAO base oils.

35

5

EXAMPLE 2

Example 1 was replicated except that 0.1 wt.% of a sulfur free molybdenum compound was added in an amount to provide 80 ppm of molybdenum to the lubricating oil composition and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

EXAMPLE 3

10

Example 1 was replicated except that 0.2 wt.% of a sulfur free molybdenum compound was added in an amount to provide 160 ppm of molybdenum to the lubricating oil composition and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

EXAMPLE 4

15

Example 1 was replicated except that 0.1 wt.% of a sulfur containing molybdenum succinimide complex was added in an amount to provide 50 ppm of molybdenum to the lubricating oil composition and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

EXAMPLE 5

20

Example 1 was replicated except that 0.2 wt.% of a sulfur containing molybdenum succinimide complex was added in an amount to provide 100 ppm of molybdenum to the lubricating oil composition and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

EXAMPLE 6

25

Example 1 was replicated except that 0.4 wt.% of a sulfur containing molybdenum succinimide complex was added in an amount to provide 200 ppm of molybdenum to the lubricating oil composition and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

COMPARATIVE EXAMPLE 1

30

Example 1 was replicated except that the ethylene propylene derived non-dispersant OCP was replaced with 0.7 wt.% of polymer concentrate which contains a hydrogenated polyisoprene star polymer coupled with divinylbenzene with an SSI of 4 and a molecular weight of 35,000 and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

COMPARATIVE EXAMPLE 2

35

Example 1 was replicated except that 0.4 wt.% of a sulfur free molybdenum compound was added in an amount to provide 320 ppm of molybdenum to the lubricating oil composition and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

COMPARATIVE EXAMPLE 3

5 Example 1 was replicated except that 0.4 wt.% of a sulfur free molybdenum compound and 0.4 wt.% of a sulfur containing molybdenum succinimide complex was added in an amount to provide 490 ppm of molybdenum to the lubricating oil and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

COMPARATIVE EXAMPLE 4

10 Example 1 was replicated except that 1.0 wt.% of a sulfur free molybdenum compound was added in an amount to provide 780 ppm of molybdenum to the lubricating oil and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

COMPARATIVE EXAMPLE 5

15 Example 11 was replicated except the ethylene propylene derived non-dispersant OCP and dispersant PMA was replaced with 4.50 wt.% of polymer concentrate which contains a hydrogenated polyisoprene star polymer coupled with divinylbenzene with an SSI of 4 and a molecular weight of 35,000 and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

COMPARATIVE EXAMPLE 6

20 Comparative Example 3 was replicated except the ethylene propylene derived non-dispersant OCP and dispersant PMA was replaced with 4.50 wt.% of polymer concentrate which contains a hydrogenated polyisoprene star polymer coupled with divinylbenzene with an SSI of 4 and a molecular weight of 35,000 and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

COMPARATIVE EXAMPLE 7

25 Example 1 was replicated except that the ethylene propylene derived non-dispersant OCP was replaced with a 6.25 wt.% of a polymer concentrate of a dispersant OCP and magnesium sulfonate was added in an amount to provide 240 ppm of Mg.

30 The isomerization level was measured by an NMR method.

Isomerization level (I) and NMR method

The isomerization level (I) of the olefin was determined by hydrogen-1 (1H) NMR. The NMR spectra were obtained on a Bruker Ultrashield Plus 400 in chloroform-d1 at 400 MHz using TopSpin 3.2 spectral processing software.

35 The isomerization level (I) represents the relative amount of methyl groups (-CH₃) (chemical shift 0.30-1.01 ppm) attached to the methylene backbone groups (-CH₂-) (chemical shift 1.01-1.38 ppm) and is defined by Formula (6) as shown below,

$$I = m/(m+n)$$

Formula (6)

- 5 where m is NMR integral for methyl groups with chemical shifts between 0.30 ± 0.03 to 1.01 ± 0.03 ppm, and n is NMR integral for methylene groups with chemical shifts between 1.01 ± 0.03 to 1.38 ± 0.10 ppm.

TESTING

- Performance evaluation of the formulations is given in Table 2. The following bench
 10 test was performed to measure wear: FZG Wear Scuffing Load Carrying Capacity Test. In order to evaluate wear performance of the automotive engine oils, the load carrying characteristics of various engine oils having different chemistries were evaluated on an FZG test rig (FZG four-square test machine) using A10 gears according to CEC-L-84-A-02. This method is useful for evaluating the scuffing load capacity potential of oils typically used with
 15 highly stressed cylindrical gearing found in many vehicle and stationary applications. The minimum load stage fail was 8 for the A10 gears at 16.6 m/s and 130 °C.

TABLE 2

Examples	DPMA of disclosure	OCP of disclosure	Salicylate Detergent	Mo (ppm)	FZG Wear
Example 1	Y	Y	Y	160	7
Example 2	Y	Y	Y	80	8
Example 3	Y	Y	Y	160	9
Example 4	Y	Y	Y	50	8
Example 5	Y	Y	Y	100	9
Example 6	Y	Y	Y	200	8
Comparative Example 1	Y	N	Y	0	6
Comparative Example 2	Y	Y	Y	320	6
Comparative Example 3	Y	Y	Y	490	6
Comparative Example 4	Y	Y	Y	780	6
Comparative Example 5	N	N	Y	200	6
Comparative Example 6	N	N	Y	490	5
Comparative Example 7	Y	N	Y	0	6

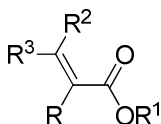
5 **WHAT IS CLAIMED IS:**

1. A lubricating oil composition having a HTHS viscosity at 150°C in a range of 1.3 to 2.9 mPa·s, comprising:

- a) more than 50 wt % of an oil of lubricating viscosity having a kinematic viscosity at 100°C in a range of 1.5 to 6.0 mm²/s;
- 10 b) a dispersant polymethacrylate (DPMA) VII having a Mw of from 200,000 g/mol to 450,000 g/mol;
- c) a non-dispersant ethylene-based olefin copolymer viscosity index improver having a Mw of from 50,000 g/mol to 150,000 g/mol and a total ethylene content of 50 wt % to 70 wt %;
- 15 d) from 50 to 300 ppm of molybdenum from a molybdenum containing compound; and
- e) less than 50 wt % of a salicylate detergent.

20 2. The lubricating oil composition of claim 1, wherein the dispersant polymethacrylate VII comprise monomer units of:

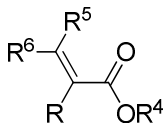
(a) 0 to 40% by weight of one or more ethylenically unsaturated ester compounds of the formula (I):



Formula I

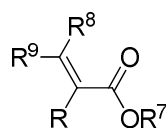
wherein R is hydrogen or methyl, R¹ is a saturated or unsaturated linear or branched alkyl radical having 1 to 5 carbon atoms or a saturated or unsaturated cycloalkyl group having 3 to 5 carbon atoms, R² and R³ are each independently hydrogen or a group of the formula - COOR' wherein R' is hydrogen or a saturated or unsaturated linear or branched alkyl group having 1 to 5 carbon atoms;

30 (b) 10 to 98% by weight, preferably 20 to 95% by weight, of one or more ethylenically unsaturated ester compounds of the formula (II)



wherein R is hydrogen or methyl, R⁴ is a saturated or unsaturated linear or branched alkyl radical having 6 to 15 carbon atoms or a saturated or unsaturated cycloalkyl group having 6 to 15 carbon atoms, R⁵ and R⁶ are each independently hydrogen or a group of the formula -COOR" in which R" is hydrogen or a saturated or unsaturated linear or branched alkyl group having 6 to 15 carbon atoms;

(c) 0 to 30% by weight, preferably 5 to 20% by weight, of one or more ethylenically unsaturated ester compounds of the formula (III):



Formula III

wherein R is hydrogen or methyl, R⁷ is a saturated or unsaturated linear or branched alkyl radical having 16 to 40 preferably 16 to 30, carbon atoms or a cycloalkyl group having 16 to 40, preferably 16 to 30, carbon atoms, R⁸ and R⁹ are each independently hydrogen or a group of the formula -COOR'" in which R'" is hydrogen or a saturated or unsaturated linear or branched alkyl group having 16 to 40, preferably 16 to 30, carbon atoms;

(d) 0 to 30% by weight of vinyl monomers;

(e) 2 to 10% by weight of at least one N-dispersant monomer.

3. The lubricating oil composition of claim 1, wherein the non-dispersant ethylene-based olefin copolymer is an ethylene propylene copolymer.
4. The lubricating oil composition of claim 1, wherein the molybdenum from the molybdenum containing compound is from 50 to 250 ppm.
5. The lubricating oil composition of claim 1, wherein the molybdenum from the molybdenum containing compound is from 50 to 200 ppm.
6. The lubricating oil composition of claim 1, wherein the molybdenum containing compound is free of sulfur.

- 5 7. The lubricating oil composition of claim 1, wherein the lubricating oil composition is a multi-grade SAE 0W-XX oil, wherein XX is any one of 8, 10, 12, 16, and 20.
8. The lubricating oil composition of claim 1, wherein the salicylate detergent is selected from a calcium salicylate, magnesium salicylate, or a combination thereof.
- 10 9. The lubricating oil composition of claim 1, wherein the non-dispersant ethylene-based olefin copolymer viscosity index improver has a total ethylene content of 55 to 65 wt. %.
10. The lubricating oil composition of claim 1, wherein the non-dispersant ethylene-based olefin copolymer viscosity index improver has a Mw of from 70,000 g/mol to 110,000 g/mol.
- 15 11. The lubricating oil composition of claim 1, wherein the dispersant polymethacrylate (DPMA) VII have a Mw of from 200,000 g/mol to 300,000 g/mol.
12. A method of improving friction and reducing wear in an internal combustion engine comprising lubricating said engine with a lubricating oil composition having a HTHS viscosity at 150°C in a range of 1.3 to 2.9 mPa·s, comprising:
- 20 a) more than 50 wt % of an oil of lubricating viscosity having a kinematic viscosity at 100°C in a range of 1.5 to 6.0 mm²/s;
- b) a dispersant polymethacrylate (DPMA) VII having a Mw of from 200,000 g/mol to 450,000 g/mol;
- c) a non-dispersant ethylene-based olefin copolymer viscosity index improver having
- 25 a Mw of from 50,000 g/mol to 150,000 g/mol and a total ethylene content of 50 wt % to 70 wt %.;
- d) from 50 to 300 ppm of molybdenum from a molybdenum containing compound; and
- e) less than 50 wt % of a salicylate detergent.
- 30
13. The method of claim 12 wherein the non-dispersant ethylene-based olefin copolymer is an ethylene propylene copolymer.

- 5 14. The method of claim 12, wherein the molybdenum from the molybdenum containing compound is from 50 to 250 ppm.
15. The method of claim 12, wherein the molybdenum from the molybdenum containing compound is from 50 to 200 ppm.
- 10 16. The method of claim 12, wherein the molybdenum containing compound is free of sulfur.
17. The method of claim 12, wherein the lubricating oil composition is a multi-grade SAE 0W-XX oil, wherein XX is any one of 8, 10, 12, 16, and 20.
18. The method of claim 12, wherein the lubricating oil composition further comprises from 1 to 10 wt.% of an ester base oil.
- 15 19. The method of claim 12, wherein the non-dispersant ethylene-based olefin copolymer viscosity index improver has a total ethylene content of 55 to 65 wt. %.
20. The method of claim 12, wherein the non-dispersant ethylene-based olefin copolymer viscosity index improver has a Mw of from 70,000 g/mol to 110,000 g/mol.
- 20 21. The method of claim 12, wherein the dispersant polymethacrylate (DPMA) VII have a Mw of from 200,000 g/mol to 300,000 g/mol.