

FIELD OF THE INVENTION

[0001] This disclosure relates to the use of C_{4 to 5} olefin polymer, such as conjugated diene polymers, having amide, imide and/or ester functionality as additives in lubricant compositions having good dispersancy in engine crankcase applications, especially in compression ignited engine applications.

BACKGROUND OF THE INVENTION

[0002] The emphasis on fuel economy has been increased in recent years. One approach to improve the fuel economy of vehicles is to design new lubricant oils that reduce friction while maintaining a good film thickness for durability and wear protection while also preventing soot-induced viscosity increase. In an attempt to improve fuel economy, the use and stipulation of low viscosity grades by Original Equipment Manufacturers (OEM) is becoming increasingly widespread. One of the challenges for the provision of engine and/or drive train transmission oils having these reduced viscosity grades is maintaining cleanliness. Such oils must be able to reduce sludge, provide good soot handling, and provide wear protection, whilst providing desired fuel economy benefits. These targets should be achieved while maintaining low levels of sulphated ash and phosphorus, as well as ensuring seal compatibility. There is a need to provide new engine oils having low viscosity grades that meet these requirements.

[0003] Base oils are typically modified by the addition of additives such as viscosity index improvers (VIIs) and/or dispersants. VIIs may be used to reduce the extent to which the viscosity of lubricants changes with temperature and are often used to formulate engine and transmission lubricants. Common VIIs typically include polymeric materials that may be derived from ethylene-propylene copolymers, polymethacrylates, hydrogenated styrene-butadiene copolymers, polyisobutylenes, etc.

[0004] During engine operation, oil-insoluble oxidation byproducts, such as soot, are produced. Dispersants help keep these byproducts suspended or in solution, thus diminishing their deposition on metal surfaces. Common dispersants include (poly)alkenylsuccinic derivatives, such as hydrocarbyl-substituted succinic anhydrides, such as polyisobutylene succinic anhydride (PIBSA) and hydrocarbyl-substituted succinimides, such as polyisobutylene succinimides (PIBSA-PAM), such as those derived from reaction of maleated polyisobutylene with N-phenyl-p-phenylenediamine. Useful dispersants include polyisobutenes, which have been modified by the ene reaction to include functional groups,

such as, succinimides, hydroxyethyl imides, succinate esters/amides, and oxazolines. Other dispersants include Mannich base derivatives of polybutenes, ethylene propylene polymers, and acrylic polymers.

[0005] Other dispersants are derived from the reaction of maleated polyalpha-olefins (such as ethylene-propylene copolymers) and polyamine. US Patent No. 6,107,257 relates to additives for lubricating oil compositions that comprise multi-functional olefin copolymer viscosity index improvers. Maleic anhydride is reacted or grafted onto an ethylene-propylene copolymer backbone in the presence of a solvent and then the grafted copolymer is reacted with a polyamine such as an N-arylphenylene diamine in the presence of a surfactant to provide a multi-functional olefin copolymer viscosity index improver. Similarly, US Patent No. 6,107,258 relates to multifunctional fuel and lubricant additives derived from acylated then aminated copolymers of C₃ to C₂₃ alpha olefins.

[0006] Still other dispersants are derived from styrenic copolymers. US Patent No. 6,248,702 discloses maleated selectively hydrogenated styrenic block copolymer (Mn 10,000, Ex 1.) reacted with aminopropyl morpholine to form a dispersant substance.

[0007] Still other dispersants are derived from copolymers of two different conjugated dienes, such as block copolymers of isoprene and butadiene. US Patent No. 5,780,540 discloses functionalized selectively hydrogenated isoprene butadiene di-block copolymers in automotive additive packages. Examples show N-phenyl-1,4-phenylenediamine used in combination with polyethylene glycol monoalcohol, 4-(3-aminopropyl morpholine) and/or 3-dibutylaminopropylamine to functionalize maleated 10,000 Mn and/or 20,000 Mn isoprene-butadiene copolymers. Examples 1 and 2 show the IB copolymer is made with 2,2' dipyridyl, which makes it less likely to have high 1,4 insertions.

[0008] Similarly, US Patent No. 6,319,881 discloses functionalized selectively hydrogenated isoprene butadiene di-block copolymers in automotive additive packages. Example IV shows a maleated selectively hydrogenated isoprene butadiene di-block copolymer (Mn 15,000) that is reacted with aminopropyl morpholine to form a morpholinopropyl succinimide adduct, that is then used as a dispersant in an additive package (Example V).

[0009] US Patent No. 5,073,600 relates to a reactive extrusion process to functionalize (for example, maleate then aminate) copolymers of conjugated diolefins typically having Mn's of 500,000 to about 3,000,000. The examples show a hydrogenated "low" molecular weight star polymer of hydrogenated homo-polyisoprene with an average of 15 arms (35,000 Mn per arm) reacted with maleic anhydride and diethylaminopropylamine in a reactive extruder.

[0010] There remains a need to provide alternative or improved engine/transmission oil compositions that meet stringent wear tests, while also providing improved wear and fuel economy. The present disclosure provides engine oil compositions including grafted, multi-functional olefin copolymers that reduce wear, as well as having acceptable soot handling, and/or engine/transmission cleanliness. Further, this disclosure addresses these needs by providing dispersant viscosity index improvers, which include narrow molecular weight distribution polymers of one or more conjugated dienes, which have been hydrogenated and functionalized. The dispersants include compositions including a copolymer of two different conjugated dienes or a homopolymer of a conjugated diene. The polymers are selectively hydrogenated to produce polymers, which have highly controlled molecular weight distributions, permitting even functionalization. Also provided are lubricant fluids, such as mineral, petrochemical, and synthetic oils, which have been modified in their dispersancy and/or viscometric properties by means of the dispersants of the disclosure.

SUMMARY OF THE INVENTION

[0011] This disclosure relates to an amide, imide, and/or ester functionalized partially or fully saturated polymer comprising C₄₋₅ olefins having:

- i) an Mw/Mn of less than 2,
- ii) a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS, as described in the Experimental section below), and
- iii) an Mn of 10,000 g/mol or more (GPC-PS) of the polymer prior to functionalization, provided that, if the polymer prior to functionalization is a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 g/mol (GPC-PS).

[0012] This disclosure also relates to an amide, imide, and/or ester functionalized partially or fully saturated polymer comprising C₄₋₅ olefins having an Mw/Mn of less than 2 (Mw and Mn determined by GPC, using polystyrene standards "GPC-PS"), a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and wherein the polymer prior to functionalization has an Mn of 30,000 g/mol or more (GPC-PS) [such as a partially or fully saturated homopolyisoprene having an Mn of 30,000 to 100,000 g/mol (GPC-PS) and containing one or more pendant amine groups], and at least about 50 % of 1,4-insertions (¹H NMR).

[0013] This disclosure also relates to an amide, imide, and/or ester functionalized hydrogenated/saturated polymer comprising (or consisting essentially of or consisting of) C₄₋₅ olefins having an Mw/Mn of less than 2 (GPC-PS), a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and wherein, if the polymer prior to functionalization is a C₄ olefin polymer such as polyisobutylene, polybutadiene, or a copolymer thereof (preferably a

polyisobutylene or a copolymer of isobutylene and butadiene), then the C₄ olefin polymer has an Mn of 10,000 g/mol or more (GPC-PS), and if the polymer prior to functionalization is a C₄/C₅ olefin copolymer such as a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 Mn (GPC-PS).

[0014] This disclosure also relates to an amide, imide, and/or ester functionalized hydrogenated/saturated polymer comprising 90 mol % or more isoprene repeat units, having an Mw/Mn of less than 2, a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and wherein the polymer prior to functionalization has an Mn of 30,000 g/mol or more (GPC-PS).

[0015] This disclosure also relates to an amide, imide, and/or ester functionalized hydrogenated/saturated homopolymer of isoprene having an Mw/Mn of less than 2, a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and wherein the polymer prior to functionalization has an Mn of 30,000 g/mol or more (as determined by GPC-PS).

[0016] Optionally, the functionalized hydrogenated/saturated polymer has an average functionality of 1.4 to 20 FG grafts/polymer chain, such as 1.4 to 15 FG grafts/polymer chain, such as 3 to 12.5 FG grafts/polymer chain, such as 4 to 10 FG grafts/polymer chain, as determined by GPC-PS as described in the Experimental section below.

[0017] Optionally, styrene repeat units may be absent in the functionalized hydrogenated/saturated polymers.

[0018] Optionally, butadiene repeat units may be absent in the functionalized hydrogenated/saturated polymers.

[0019] Optionally the functionalized hydrogenated/saturated polymer may be not homopolyisobutylene.

[0020] Optionally, the functionalized hydrogenated/saturated polymer may be not a copolymer of isoprene and butadiene.

[0021] This disclosure relates to an amide, imide, and/or ester functionalized hydrogenated polymer of one or more C₄₋₅ conjugated dienes described herein obtained by reacting fully or partially (such as at least 90 % saturated) hydrogenated polymers of C₄₋₅ conjugated dienes having an Mw/Mn of less than 2, with an acylating agent, such as maleic acid or maleic anhydride, and thereafter reacting the acylated polymer with an amine (such as a polyamine or a monoamine) to form an imide, amide, or combination thereof.

[0022] This disclosure relates to polymers containing one or more pendant amine groups and comprising or resulting from the admixing of: at least partially (such as at least 90 %, preferably completely) hydrogenated C₄₋₅ olefin polymers with an acylating agent, such as

maleic acid or maleic anhydride, and thereafter reacting the acylated polymer with a polyamine, to form an imide, amide or combination thereof.

[0023] This disclosure also relates to lubricating oil compositions and additive/component concentrates comprising or resulting from the admixing of the functionalized hydrogenated/saturated polymers described herein.

[0024] This disclosure also relates to lubricating oil compositions comprising or resulting from the admixing of the functionalized hydrogenated/saturated polymers described herein and at least 40 wt % hydrocarbon basestock oil, such as group I, II, and/or III oil, such as a group II oil.

[0025] This disclosure also relates to additive concentrates comprising or resulting from the admixing of the functionalized hydrogenated/saturated polymers described herein and at least 1 wt % hydrocarbon basestock oil, such as group I, II, and/or III oil, such as a group I oil.

[0026] This disclosure also relates to functionalized copolymer comprising or resulting from the admixing of the functionalized hydrogenated/saturated polymers described herein and at least 1 wt % hydrocarbon basestock oil, such as group I, II, or III oil, such as a group III oil.

[0027] According to another aspect of the present disclosure, there is provided the use of the lubricating oil composition described above for providing enhanced soot dispersancy and reduced wear in an internal combustion engine, such as a turbocharged spark-ignited engine, a spark-assisted compression engine, a compression-ignited engine (such as a diesel engine, such as a heavy-duty diesel engine or a marine engine), or combination thereof, comprising lubricating the engine with the lubricating oil compositions described herein and operating the engine.

[0028] According to another aspect of the present disclosure, there is provided the use of the lubricating oil composition described above for providing enhanced soot dispersancy and reduced wear in an internal combustion engine built to run solely on natural gas (which is typically spark ignited) or on a dual-fuel combination, combining natural gas with hydrocarbon (such as diesel) fuel, which is compressed in the combustion chamber until it ignites, a process known as high-pressure direct injection (HPDI).

[0029] According to yet a further aspect of the present disclosure, there is provided the use of the lubricating oil composition described above for providing compositions, as described herein, having a valve train wear (Cummins ISB Engine Test, ASTM D7484-21) of 55 μm or less.

[0030] According to yet a further aspect of the present disclosure, the lubricating oil compositions described herein have a valve train wear (Cummins ISB Engine Test, ASTM

D7484-21, μm) that is at least 10 μm less than the valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm), of a comparative lubricating oil composition having a valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm) of 65 μm or less, that has the same composition as the inventive lubricating oil composition except that the amide, imide, and/or ester functionalized partially or fully saturated polymer is replaced at same amount (wt %) by a functionalized ethylene-propylene copolymer prepared by maleating ethylene-propylene copolymer (Trilene™ CP-80, Lion Elastomers, Mn approx 23,000 g/mol, E/P approx 41/59) then reacting with amine N-phenyl-p-phenylenediamine (ADPA) to obtain an ethylene-propylene copolymer containing one or more pendant amine groups and having 35 mass % active ingredient.

[0031] According to yet a further aspect of the present disclosure, there is provided the use of the lubricating oil composition described above, where the lubricating oil composition has:

- a) an SAE viscosity grade of 20W-X, 15W-X, 10W-X, 5W-X or 0W-X, where X represents any one of 8, 12, 16, 20, 30, 40 and 50 (such as 30 or 40), and
- b) valve train rocker arm wear of 150 mg or less (as determined by Ford 6.7L Power Stroke Diesel Engine Test for soot induced wear and viscosity control), and
- c) soot induced camshaft wear of 55 μm or less (Cummins ISB Engine Test, ASTM D7484-21); and
- d) soot dispersancy of 5 % soot or more (as determined by Mack T11 Test for Soot-Induced Viscosity Control ASTM D7156-19, measured at 12 cSt viscosity increase).

In embodiments, the lubricating oil composition may contain one or more linear alpha olefins (such as a blend of C₁₂₋₂₄ linear alpha-olefins, such as a blend of C₁₄₋₁₈ linear alpha-olefins).

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] Figure 1 (Fig. 1) is a graph of a GPC calibration curve prepared from ODSA-ADPA samples at 0.01, 0.02, 0.03, 0.04, and 0.05 mg/ml.

[0033] Figure 2 (Fig. 2) is a representative chromatogram for GPC analysis as described in the Experimental section below.

[0034] Figure 3 (Fig. 3) is the GPC trace for Example 10A.

[0035] Figure 4 (Fig. 4) is the GPC trace for Example 10B.

[0036] Figure 5 (Fig. 5) is the GPC trace for Example 10C.

[0037] Figure 6 (Fig. 6) is the GPC trace for Example 10D.

DEFINITIONS

[0038] For purposes of this specification and all claims to this invention, the following words and expressions, if and when used, have the meanings ascribed below.

[0039] For purposes herein, the new numbering scheme for the Periodic Table of the Elements is used as set out in CHEMICAL AND ENGINEERING NEWS, 63(5), 27 (1985), *i.e.*, Alkali metals are group 1 metals (*e.g.*, Li, Na, K, etc.) and Alkaline earth metals are group 2 metals (*e.g.*, Mg, Ca, Ba, etc.).

[0040] The term "comprising" or any cognate word specifies the presence of stated features, steps, or integers or components, but does not preclude the presence or addition of one or more other features, steps, integers, components or groups thereof. The expressions "consists of" or "consists essentially of" or cognates may be embraced within "comprises" or cognates, wherein "consists essentially of" permits inclusion of substances not materially affecting the characteristics of the composition to which it applies.

[0041] The term "LOC" means lubricating oil composition.

[0042] The term "major amount" means more than 50 mass % of a composition, such as more than 60 mass % of a composition, such as more than 70 mass % of a composition, such as from 80 to 99.009 mass % of a composition, such as from 80 to 99.9 from 80 to 99.009 mass % of a composition, of a composition based upon the mass of the composition.

[0043] The term "minor amount" means 50 mass % or less of a composition; such as 40 mass % or less of a composition; such as 30 mass % or less of a composition, such as from 20 to 0.001 mass %, such as from 20 to 0.1 mass %, based upon the mass of the composition.

[0044] The term "mass %" means mass percent of a component, based upon the mass of the composition as measured in grams, unless otherwise indicated, and is alternately referred to as weight percent ("weight %", "wt %", or "%w/w").

[0045] The term "active ingredient" (also referred to as "a.i." or "A.I.") refers to additive material that is neither diluent nor solvent. Unless otherwise indicated, amounts herein are described as active ingredient.

[0046] The terms "oil-soluble" and "oil-dispersible," or cognate terms, used herein do not necessarily indicate that the compounds or additives are soluble, dissolvable, miscible, or are capable of being suspended in the oil in all proportions. These do mean, however, that they are, for example, soluble or stably dispersible in oil to an extent sufficient to exert their intended effect in the environment in which the oil is employed. Moreover, the additional incorporation of other additives may also permit incorporation of higher levels of a particular additive, if desired.

[0047] The terms "group" and "radical" are used interchangeably herein.

[0048] The term "hydrocarbon" means a compound of hydrogen and carbon atoms. A "heteroatom" is an atom other than carbon or hydrogen. When referred to as "hydrocarbons," particularly as "refined hydrocarbons," the hydrocarbons may also contain one or more heteroatoms or heteroatom-containing groups (such as halo, especially chloro and fluoro, amino, alkoxyl, mercapto, alkylmercapto, nitro, nitroso, sulfoxy, etc.) in minor amounts (*e.g.*, where the heteroatom(s) do not substantially alter the hydrocarbon properties of the hydrocarbon compound).

[0049] The term "hydrocarbyl" means a radical that contains hydrogen and carbon atoms. Preferably, the group consists essentially of, more preferably consists only of, hydrogen and carbon atoms, unless specified otherwise. Preferably, the hydrocarbyl group comprises an aliphatic hydrocarbyl group. The term "hydrocarbyl" includes "alkyl," "alkenyl," "alkynyl," and "aryl" as defined herein. Hydrocarbyl groups may contain one or more atoms/groups other than carbon and hydrogen provided they do not affect the essentially hydrocarbyl nature of the hydrocarbyl group. Those skilled in the art will be aware of such atoms/groups (*e.g.*, halo, especially chloro and fluoro, amino, alkoxyl, mercapto, alkylmercapto, nitro, nitroso, sulfoxy, etc.).

[0050] The term "alkyl" means a radical of carbon and hydrogen (such as a C₁ to C₃₀, such as a C₁ to C₁₂ group). Alkyl groups in a compound are typically bonded to the compound directly via a carbon atom. Unless otherwise specified, alkyl groups may be linear (*i.e.*, unbranched) or branched, be cyclic, acyclic, or part cyclic/acyclic. Preferably, the alkyl group comprises a linear or branched acyclic alkyl group. Representative examples of alkyl groups include, but are not limited to, methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, iso-butyl, tert-butyl, n-pentyl, iso-pentyl, neo-pentyl, hexyl, heptyl, octyl, dimethyl hexyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, icosyl and triacontyl.

[0051] The term "alkenyl" means a radical of carbon and hydrogen (such as a C₂ to C₃₀ radical, such as a C₂ to C₁₂ radical) having at least one double bond. Alkenyl groups in a compound are typically bonded to the compound directly via a carbon atom. Unless otherwise specified, alkenyl groups may be linear (*i.e.*, unbranched) or branched, be cyclic, acyclic or part cyclic/acyclic.

[0052] The term "alkylene" means a C₁ to C₂₀, preferably a C₁ to C₁₀, bivalent saturated aliphatic radical, which may be linear or branched. Representative examples of alkylene include methylene, ethylene, propylene, butylene, pentylene, hexylene, heptylene, octylene,

nonylene, decylene, 1-methyl ethylene, 1-ethyl ethylene, 1-ethyl-2-methyl ethylene, 1,1-dimethyl ethylene and 1-ethyl propylene.

[0053] An "olefin", alternatively referred to as "alkene," is a linear, branched, or cyclic compound of carbon and hydrogen having at least one double bond. For purposes of this specification and the claims appended thereto, when a polymer or copolymer is referred to as comprising an olefin, the olefin present in such polymer or copolymer is the polymerized form of the olefin. For example, when a copolymer is said to have an "isoprene" content of 55 wt % to 95 wt %, it is understood that the mer unit in the copolymer is derived from isoprene in the polymerization reaction and said derived units are present at 55 wt % to 95 wt %, based upon the weight of the copolymer. A "polymer" has two or more of the same or different mer units. A "homopolymer" is a polymer having mer units that are the same. A "copolymer" is a polymer having two or more mer units that are different from each other. "Different" as used to refer to mer units indicates that the mer units differ from each other by at least one atom or are different isomerically. An "isoprene polymer" or "isoprene copolymer" is a polymer or copolymer comprising at least 50 mol % isoprene derived units, a "butadiene polymer" or "butadiene copolymer" is a polymer or copolymer comprising at least 50 mol % butadiene derived units, and so on. Likewise, when a polymer is referred to as a "partially or fully saturated polymer comprising C₄₋₅ olefins," the C₄₋₅ olefin(s) present in such polymer or copolymer are the polymerized form of the olefin(s), and the polymer has been partially or fully saturated (such as by hydrogenation) after polymerization of the monomers.

[0054] The term "alkynyl" means a C₂ to C₃₀ (such as a C₂ to C₁₂) radical, which includes at least one carbon-to-carbon triple bond.

[0055] The term "aryl" means a group containing at least one aromatic ring, such a cyclopentadiene, phenyl, naphthyl, anthracenyl, and the like. Aryl groups are typically C₅ to C₄₀ (such as C₅ to C₁₈, such as C₆ to C₁₄) aryl groups, optionally substituted by one or more hydrocarbyl groups, heteroatoms, or heteroatom-containing groups (such as halo, hydroxyl, alkoxy and amino groups). Preferred aryl groups include phenyl and naphthyl groups and substituted derivatives thereof, especially phenyl, and alkyl substituted derivatives of phenyl.

[0056] The term "substituted" means that a hydrogen atom has been replaced with hydrocarbon group, a heteroatom, or a heteroatom-containing group. An alkyl substituted derivative means a hydrogen atom has been replaced with an alkyl group. An "alkyl substituted phenyl" is a phenyl group where a hydrogen atom has been replaced by an alkyl group, such as a C₁ to C₂₀ alkyl group, such as methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, iso-butyl, tert-butyl, n-pentyl, iso-pentyl, neo-pentyl, hexyl, heptyl, octyl, dimethyl hexyl, nonyl,

decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, icosyl and/or triacontyl.

[0057] The term "halogen" or "halo" means a group 17 atom or a radical of group 17 atom, such as fluoro, chloro, bromo, and iodo.

[0058] The term "ashless" in relation to an additive means the composition does not include a metal.

[0059] The term "ash-containing" in relation to an additive means the composition includes a metal.

[0060] The term "effective amount" in respect of an additive means an amount of such an additive in a lubricating oil composition so that the additive provides the desired technical effect.

[0061] The term "effective minor amount" in respect of an additive means an amount of such an additive of less than 50 mass % of the lubricating oil composition so that the additive provides the desired technical effect.

[0062] The term "ppm" means parts per million by mass, based on the total mass of the lubricating oil composition, unless otherwise indicated.

[0063] The term "metal content" of a lubricating oil composition or of an additive component, for example, magnesium content, molybdenum content or total metal content (*i.e.*, the sum of all individual metal contents), is measured by ASTM D5185.

[0064] The term "aliphatic hydrocarbyl fatty acid" means a monocarboxylic acid having an aliphatic C₇ to C₂₉, preferably a C₉ to C₂₇, most preferably a C₁₁ to C₂₃ hydrocarbyl chain. Such compounds may be referred to herein as aliphatic (C₇ to C₂₉), more preferably (C₉ to C₂₇), most preferably (C₁₁ to C₂₃), hydrocarbyl monocarboxylic acid(s) or hydrocarbyl fatty acid(s) (wherein C_x to C_y designates the total number of carbon atoms in the aliphatic hydrocarbyl chain of the fatty acid, the fatty acid itself due to the presence of the carboxyl carbon atom includes a total of C_x+1 to C_y+1 carbon atoms). Preferably, the aliphatic hydrocarbyl fatty acid, inclusive of the carboxyl carbon atom, has an even number of carbon atoms. The aliphatic hydrocarbyl chain of the fatty acid may be saturated or unsaturated (*i.e.*, includes at least one carbon-to-carbon double bond); preferably, the aliphatic hydrocarbyl chain is unsaturated and includes at least one carbon-to-carbon double bond – such fatty acids may be obtained from natural sources (*e.g.*, derived from animal or vegetable oils) and/or by reduction of the corresponding saturated fatty acid. It will be appreciated that a proportion of the aliphatic hydrocarbyl chain(s) of the corresponding aliphatic hydrocarbyl fatty acid ester(s) is unsaturated (*i.e.*, includes at least one carbon-to-carbon double bond) to permit reaction with

other agents, such as sulfur, to form the corresponding functionalized, such as sulfurized, aliphatic hydrocarbyl fatty acid ester(s).

[0065] The term "aliphatic hydrocarbyl fatty acid ester" means an ester obtainable by converting the monocarboxylic acid functional group of the corresponding aliphatic hydrocarbyl fatty acid into an ester group. Suitably, the monocarboxylic acid functional group of the aliphatic hydrocarbyl fatty acid is converted to a hydrocarbyl ester, preferably a C₁ to C₃₀ aliphatic hydrocarbyl ester, such as an alkyl ester, preferably a C₁ to C₆ alkyl ester, especially a methyl ester. Alternatively, or additionally, the monocarboxylic acid functional group of the aliphatic hydrocarbyl fatty acid may be in the form of the natural glycerol ester. Accordingly, the term "aliphatic hydrocarbyl fatty acid ester" embraces aliphatic hydrocarbyl fatty acid glycerol ester(s) and aliphatic hydrocarbyl fatty acid C₁ to C₃₀ aliphatic hydrocarbyl ester(s), [e.g., aliphatic hydrocarbyl fatty acid alkyl ester(s), more preferably aliphatic hydrocarbyl fatty acid C₁ to C₆ alkyl ester(s), especially aliphatic hydrocarbyl fatty acid methyl ester(s)]. Suitably, the term "aliphatic hydrocarbyl fatty acid ester" embraces aliphatic (C₇ to C₂₉) hydrocarbyl, more preferably aliphatic (C₉ to C₂₇) hydrocarbyl, most preferably aliphatic (C₁₁ to C₂₃) hydrocarbyl fatty acid glycerol ester(s) and aliphatic (C₇ to C₂₉) hydrocarbyl, more preferably aliphatic (C₉ to C₂₇) hydrocarbyl, most preferably aliphatic (C₁₁ to C₂₃) hydrocarbyl fatty acid C₁ to C₃₀ aliphatic hydrocarbyl ester(s). Suitably, to permit functionalization, such as sulfurization, of the aliphatic hydrocarbyl fatty acid ester(s) a proportion of the aliphatic hydrocarbyl chain(s) of the fatty acid ester(s) is unsaturated and includes at least one carbon-to-carbon double bond.

[0066] The term "sulfurized aliphatic hydrocarbyl fatty acid ester" means a compound obtained by sulfurizing an aliphatic hydrocarbyl fatty acid ester as defined herein.

[0067] The term "absent" as it relates to components included within the lubricating oil compositions described herein and the claims thereto means that the particular component is present at 0 wt %, based upon the weight of the lubricating oil composition, or if present in the lubricating oil composition the component is present at levels that do not impact the lubricating oil composition properties, such as less than 10 ppm, or less than 1 ppm or less than 0.001 ppm. When the term "absent" is used in relation to monomer reactants and/or to repeat units in (co)polymers described herein, it means present at 0 wt%, based upon the weight of all (co)monomers in the (co)polymer, or, if present at all, at levels so low that they do not substantially impact the physical properties of the (co)polymer, such as at 0.2 wt% or less or at 0.1 wt% or less.

[0068] As used herein, Mn is number average molecular weight, Mw is weight average molecular weight, and Mz is z average molecular weight. Molecular weight distribution (MWD), also referred to as polydispersity index (PDI), is defined to be Mw divided by Mn. Unless otherwise noted, all molecular weight units (*e.g.*, Mw, Mn, Mz) are reported in g/mol.

[0069] Total Base Number also referred to as "TBN," in relation to an additive component or of a lubricating oil composition (*i.e.*, unused lubricating oil composition) means total base number as measured by ASTM D2896 and reported in units of mgKOH/g.

[0070] Total Acid Number ("TAN") is determined by ASTM D664.

[0071] Phosphorus, Boron, Calcium, Zinc, Molybdenum, Sodium, Silicon, and Magnesium content are measured by ASTM D5185.

[0072] Sulfur content in oil formulations is measured by ASTM D5185.

[0073] Sulfated ash ("SASH") content is measured by ASTM D874.

[0074] Kinematic viscosity (KV100, KV40) is determined pursuant to ASTM D445-19a and reported in units of cSt, unless otherwise specified.

[0075] Viscosity index is determined according to ASTM D2270.

[0076] Saponification number is determined by ASTM D94, and reported in units of mgKOH/g.

[0077] Average functionality [also referred to as Average Functionality Value (Fv)] and Functionality Distribution (Fd) value are determined by Gel Permeation Chromatography using polystyrene standards as described in the Experimental section below.

[0078] Unless otherwise indicated, all percentages reported are mass % on an active ingredient basis, *i.e.*, without regard to carrier or diluent oil, unless otherwise indicated.

[0079] Also, it will be understood that various components used, essential as well as optimal and customary, may react under conditions of formulation, storage or use and that the disclosure also provides the product obtainable or obtained as a result of any such reaction.

[0080] Further, it is understood that any upper and lower quantity, range and ratio limits set forth herein may be independently combined.

[0081] Also, it will be understood that the preferred features of each aspect of the present disclosure are regarded as preferred features of every other aspect of the present disclosure. Accordingly, preferred and more preferred features of one aspect of the present disclosure may be independently combined with other preferred and/or more preferred features of the same aspect or different aspects of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0082] The features of the disclosure relating, where appropriate, to each and all aspects of the disclosure, will now be described in more detail as follows.

[0083] The lubricating oil compositions of the disclosure comprise components that may or may not remain the same chemically before and after mixing with an oleaginous carrier (such as a base oil) and/or other additives. This disclosure encompasses compositions which comprise the components before mixing, or after mixing, or both before and after mixing.

Lubricating Oil Compositions

[0084] This disclosure relates to lubricating oil compositions (also referred to as "LOC," "lubricant compositions," "lubricating compositions," or "lubricant oil compositions") comprising or resulting from the admixing of:

- (a) from 1 to 99 mass % (alternately 30 to 95 mass %, alternately 50 to 90 mass %, alternately 60 to 95 mass %, alternately 70 to 85 mass %) of one or more base oils, based upon the weight of the lubricating composition;
- (b) from 0.10 to 20 mass % (in particular 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %, alternately 0.5 to 1 mass %), based upon the weight of the composition, of one or more amide, imide, and/or ester functionalized partially or fully saturated polymers comprising C₄₋₅ olefins having:
 - i) an Mw/Mn of less than 2,
 - ii) a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and
 - iii) an Mn of 10,000 g/mol or more (GPC-PS) of the polymer(s) prior to functionalization, provided that, if the polymer(s) prior to functionalization is(are) a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 g/mol (GPC-PS),

where the lubricating oil composition may preferably exhibit:

- 1) an SAE viscosity grade of 20W-X, 15W-X, 10W-X, 5W-X, or 0W-X (such as 15W-X, 10W-X, 5W-X), where X represents any one of 8, 12, 16, 20, 30, 40, and 50 (such as 30 and 40); and
- 2) a valve train rocker arm wear of 150 mg or less, such as 100 mg or less, such as 80 mg or less (as determined by Ford 6.7L Power Stroke Diesel Engine Test for soot induced wear and viscosity control); and
- 3) a soot induced camshaft wear of 55 μ m or less, such as 50 μ m or less, such as 40 μ m or less (as determined by Cummins ISB Diesel Engine Test for valve train wear control); and

4) a soot dispersancy of 5 % soot or more, such as 6% soot or more, such as 6.5 % soot or more (as determined by Mack T11 Test for Soot-Induced Viscosity Control ASTM D7156-19, measured at 12 cSt viscosity increase).

[0085] This disclosure also relates to lubricating oil compositions comprising or resulting from the admixing of:

(i) from 1 to 99 mass % (alternately 30 to 95 mass %, alternately 50 to 90 mass %, alternately 60 to 95 mass %, alternately 70 to 85 mass %) of one or more base oils, based upon the weight of the lubricating composition;

(ii) from 0.01 to 20 mass % (in particular 0.1 to 12 mass %, alternately 0.1 to 8 mass %), based on total weight of the lubricating composition, of one or more dispersants (such as blends of dispersants);

(iii) from 0.10 to 20 mass % (in particular 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %), based upon the weight of the composition, of one or more detergents;

(iv) from 0.001 to 10 wt % (in particular, 0.01 to 5 wt %, alternately 0.1 to 3 mass %, alternately 0.25 to 1.5 mass %, alternately 0.5 to 1.0 mass %), based on total weight of the lubricating composition, of one or more antiwear agents (such as blends of antiwear agents, such as zinc dialkyl dithio phosphate);

(v) from 0.10 to 20 mass % (in particular 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %, alternately 0.5 to 1 mass %), based upon the weight of the composition, of one or more amide, imide, and/or ester functionalized partially or fully saturated polymers comprising C₄₋₅ olefins having:

i) an Mw/Mn of less than 2,

ii) a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and

ii) an Mn of 10,000 g/mol or more (GPC-PS) of the polymer(s) prior to functionalization, provided that, if the polymer(s) prior to functionalization is(are) a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 g/mol (GPC-PS),

where the lubricating oil composition may preferably exhibit:

1) an SAE viscosity grade of 20W-X, 15W-X, 10W-X, 5W-X, or 0W-X (such as 15W-X, 10W-X, 5W-X), where X represents any one of 8, 12, 16, 20, 30, 40, and 50 (such as 30 and 40);

2) a valve train rocker arm wear of 150 mg or less, such as 100 mg or less, such as 80 mg or less (as determined by Ford 6.7L Power Stroke Diesel Engine Test for soot induced wear and viscosity control);

- 3) a soot induced camshaft wear of 55 μm or less, such as 50 μm or less, such as 40 μm or less (as determined by Cummins ISB Diesel Engine Test for valve train wear control); and
- 4) a soot dispersancy of 5 % soot or more, such as 6% soot or more, such as 6.5 % soot or more (as determined by Mack T11 Test for Soot-Induced Viscosity Control ASTM D7156-19, measured at 12 cSt viscosity increase).

[0086] The instant disclosure also relates to a lubricant composition of an oil of lubricating viscosity and from 0.1 wt % to 20 wt % of a polymeric compound comprising an acylated polymer having a number average molecular weight (Mn) of about 25,000 to about 50,000 g/mol and in which the polymer comprises olefins having 4 to 5 carbon atoms, preferably wherein the acylated polymer is further reacted with an amine to form an amide, imide or combinations thereof. Preferably the reaction product may be an amide, imide, and/or ester functionalized partially or fully saturated polymers comprising C₄₋₅ olefins having: i) an Mw/Mn of less than 2, ii) a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and iii) an Mn of 10,000 g/mol or more (GPC-PS) of the polymer prior to functionalization, provided that, if the polymer prior to functionalization is a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 g/mol (GPC-PS).

[0087] This disclosure also relates to lubricating oil compositions comprising or resulting from the admixing of:

- A) from 1 to 99 mass % (alternately 30 to 95 mass %, alternately 50 to 90 mass %, alternately 60 to 95 mass %, alternately 70 to 85 mass %) based upon the weight of the lubricating oil composition, of one or more base oils;
- B) from 0.10 to 20 mass % (in particular, 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %), based on total weight of the lubricating oil composition, of one or more amide, imide, and/or ester functionalized partially or fully saturated polymers described herein;
- C) from 0.10 to 20 mass % (in particular, 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %), based upon the weight of the lubricating oil composition, of one or more detergents (such as blends of detergents);
- D) optionally, from 0.01 to 5 wt % (in particular 0.1 to 4 mass %, alternately 0.25 to 3 mass %, alternately 0.045-0.15 mass %), based on total weight of the lubricating oil composition, of one or more friction modifiers (such as blends of friction modifiers);
- E) optionally, from 0.01 to 10 wt % (in particular, 0.01 to 5 wt %, alternately 0.01 to 3 mass %, alternately 0.1 to 1.5 mass %), based on total weight of the lubricating oil composition, of one or more antioxidants (such as blends of antioxidants);

- F) optionally, from 0.01 to 5 wt % (in particular, 0.01 to 3 mass %, alternately 0.1 to 1.5 mass %), based on total weight of the lubricating oil composition, of one or more pour point depressants (such as blends of pour point depressants);
- G) optionally, from 0.001 to 5 wt % (in particular, 0.01 to 3 mass %, alternately 0.1 to 1.5 mass %), based on total weight of the lubricating oil composition, of one or more anti-foam agents (such as blends of anti-foam agents);
- H) optionally, from 0.001 to 10 wt % (in particular, 0.01 to 6 wt %, alternately 0.01 to 5 mass %, alternately 0.1 to 4 mass %, alternately 0.1 to 2 mass %, alternately 0.1 to 1 mass %), based on total weight of the lubricating oil composition, of one or more viscosity modifiers (such as blends of viscosity modifiers);
- I) optionally, from 0.01 to 20 wt % (in particular, 0.1 to 12 mass %, alternately 0.1 to 8 mass %), based on total weight of the lubricating oil composition, of one or more dispersants (such as blends of dispersants);
- J) optionally, from 0.01 to 5 wt % (in particular, 0.1 to 3 mass %, alternately 0.1 to 1.5 mass %), based on total weight of the lubricating oil composition, of one or more inhibitors and/or anti-rust agents (such as blends of inhibitors and /or anti-rust agents);
- K) from 0.001 to 10 wt % (in particular, 0.01 to 5 wt %, alternately 0.1 to 3 mass %, alternately 0. to 1.5 mass %), based on total weight of the lubricating oil composition, of one or more antiwear agents (such as blends of antiwear agents, such as ZDDP);
- M) optionally, from 0.01 to 5 wt % (in particular, 0.05 to 2 mass %, alternately 0.1 to 1 mass %), based on total weight of the lubricating oil composition, of one or more seal compatibility agents, such as seal swell agents, and/or
- O) optionally, from 0.01 to 5 wt % (in particular, 0.1 to 3 mass %, alternately 0.1 to 1.5 mass %), based on total weight of the lubricating oil composition, of one or more unsaturated C₁₂-C₆₀ hydrocarbons (such as C₁₂-C₂₄ linear alpha-olefins (LAOs), oligomers/polymers of polyisobutylenes, and/or blends thereof).

[0088] For purposes of this disclosure, component B) functionalized polymers are not added in the elements C, D, E, F G, H, I, J, K, M, and/or O above for determining weight percentages, even though they may show similar properties, *e.g.*, element B) functionalized polymers may impact wear positively, but is not added into element K) for determining weight percent of antiwear agents. Specifically, compositions according to the present disclosure may contain an additive having a different enumerated function that are also aminated (for example, the dispersant component PIBSA-PAM and others described below in the dispersant section).

These additives are not included as functionalized polymer for purposes of determining the amount of functionalized polymer in a lubricating oil composition or concentrate herein.

[0089] In embodiments, all of elements D, E, F G, H, I, J, K, M, and O are present in addition to the base oil, detergent, and the one or more functionalized polymers described herein.

[0090] In embodiments, elements D, E, F G, H, I, and J are present in addition to the base oil, detergent, and the one or more functionalized polymers described herein.

[0091] In embodiments, elements I, F, and G are present in addition to the base oil, detergent, and the one or more functionalized polymers described herein.

[0092] In embodiments, element K is present in addition to the base oil, detergent, and the one or more functionalized polymers described herein.

[0093] Suitably, the lubricant composition may have a total base number (TBN) of 4 to 15 mgKOH/g, preferably 5 to 12 mgKOH/g, such as 7 to 12 mgKOH/g, such as 8 to 11 mgKOH/g, as measured by ASTM D2896.

[0094] According to yet a further aspect of the present disclosure, the lubricating oil compositions described herein may have a valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm) that is at least 10 μm less (such as at least 20 μm less, such as at least 30 μm less,) than the valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm) of a comparative lubricating oil composition having a valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm) of 65 μm or less (such as 15 to 65 μm , such as 35 to 65 μm), that has the same composition as the inventive lubricating oil composition except that the amide, imide, and/or ester functionalized partially or fully saturated polymer is replaced at same amount (wt %) by a functionalized ethylene-propylene copolymer prepared by maleating ethylene-propylene copolymer (Trilene™ CP-80, Lion Elastomers, Mn approx 23,000 g/mol, E/P approx 41/59) then reacting with amine N-phenyl-p-phenylenediamine (ADPA) to obtain an ethylene-propylene copolymer containing one or more pendant amine groups and having 35 mass % active ingredient.

[0095] According to yet a further aspect of the present disclosure, the lubricating oil compositions described herein may have a valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm) that is at least 10 % less (alternately at least 20 % less, alternately at least 30 % less, alternately at least 40 % less, alternately at least 50 % less) than the valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm) of a comparative lubricating oil composition having a valve train wear (Cummins ISB Engine Test, ASTM D7484-21, μm) of

65µm or less (such as 15 to 65 µm, such as 35 to 65 µm), that has the same composition as the inventive lubricating oil composition except that the amide, imide, and/or ester functionalized partially or fully saturated polymer is replaced at same amount (wt %) by a functionalized ethylene-propylene copolymer prepared by maleating ethylene-propylene copolymer (Trilene™ CP-80, Lion Elastomers, Mn approx 23,000 g/mol, E/P approx 41/59) then reacting with amine N-phenyl-p-phenylenediamine (ADPA) to obtain an ethylene-propylene copolymer containing one or more pendant amine groups and having 35 mass % active ingredient.

[0096] The lubricating compositions of the present disclosure may contain low levels of phosphorus, namely not greater than 1600, preferably not greater than 1200, more preferably not greater than 800, such as 1 to 1600, such as 50 to 1200, such as 100 to 800 parts per million (ppm) by mass of phosphorus, expressed as atoms of phosphorus, based on the total mass of the lubricating compositions, as measured by ASTM D5185.

[0097] Suitably, the lubricant composition may have a phosphorus level of 1200 ppm or less, alternately 1000 ppm or less, alternately 800ppm or less, as measured by ASTM D5185.

[0098] The lubricating compositions of the present disclosure may contain a ratio of atoms of Magnesium to atoms of Calcium based on the total mass of the lubricating compositions, as measured by ASTM D5185, of at least to 0.5, preferably at least 0.6, more preferably at least 0.65.

[0099] Typically, the lubricating compositions may contain low levels of sulfur. Preferably, the lubricating composition contains up to 0.4, more preferably up to 0.3, most preferably up to 0.2, such as 0.1 to 0.4 mass % sulfur, based on the total mass of the lubricating oil composition, as measured by ASTM D5185.

[0100] Typically, the lubricating compositions may contain low levels of sulfated ash, such as 1.2 % or less, such as 1.0 mass % or less, preferably 0.9 mass or less %, preferably 0.8 mass % or less, alternately 0.0001 to 0.5 mass % or less sulfated ash, based on the total mass of the lubricating composition, as measured by ASTM D874-13a (2018).

[0101] Generally, the kinematic viscosity at 100° C ("KV100") of the lubricating composition may range from 2 to 30 cSt, such as 2 to 20 cSt, such as 5 to 15 cSt as determined according to ASTM D 445-19a).

[0102] In embodiments, the kinematic viscosity at 100° C ("KV100") of the lubricating composition may range from 6 to 17 cSt, such as 9 to 16.3 cSt, such as 9.3 to less than 12.5 cSt, such as 12.5 to less than 16.3 cSt, as determined according to ASTM D 445-19a).

[0103] Generally, the total base number of the lubricating composition may range from 1 to 30, such as 5 to 15 mgKOH/g, (as determined according to ASTM D2896).

[0104] Preferably, the lubricating composition of the present disclosure may be a multigrade oil identified by the viscometric descriptor SAE 20W-X, SAE 15W-X, SAE 10W-X, SAE 5W-X or SAE 0W-X, where X represents any one of 8, 12, 16, 20, 30, 40, and 50; the characteristics of the different viscometric grades can be found in the SAE J300 classification. Alternately, the lubricating composition may be the form of viscosity grade SAE 15W-X, SAE 10W-X, SAE 5W-X or SAE 0W-X, such as in the form of SAE 15W-X or SAE 10W-X, wherein X represents any one of 8, 12, 16, 20, 30, 40, and 50. Preferably X is 8, 12, 16, or 20. Alternately, the lubricating composition of the present disclosure may be a multigrade oil identified by the viscometric descriptor SAE 10W-30, 15W-40, 5W-30, 5W-40, 10W-40, 5W-50. (See standard SAE J300 published January 2015 by SAE International, formerly known as Society of Automotive Engineers).

[0105] Alternately, the lubricating composition may have a SAE viscosity grade of 0W-Y, wherein Y may be 12, 16, or 20. In one embodiment, the lubricating composition has an SAE viscosity grade of 0W-12.

[0106] Optionally, the lubricating composition may be absent phenolic antioxidant.

[0107] In embodiments, the lubricating oil composition may comprise less than 75 ppm boron, alternately less than 60 ppm boron, alternately from 1 to 70 ppm boron. Alternately, the LOC may be absent boron.

[0108] In embodiments, the lubricating oil composition may comprise less than 20 (such as less than 15, such as less than 10, such as less than 5, such as less than 3, such as less than 1) mass %, functionalized (such as aminated) polybutene (such as polyisobutylene), such as PIBSA-PAM. In embodiments, the lubricating oil composition may comprise, may be substantially free of, or may be absent, functionalized (such as aminated) polybutene (such as polyisobutylene), such as PIBSA-PAM.

[0109] In embodiments, the lubricating oil composition may comprise acylated polymers, such as polyisobutylene succinic acid (PIBSA), optionally having an Mn of 500 to 50,000 g/mol, such as 600 to 5,000 g/mol, such as 700 to 3000 g/mol. In embodiments, the lubricating oil composition may comprise acylated polymers, such as polyisobutylene succinic acid, having an Mn of 500 to 1600 g/mol, such as 700 to 1200 g/mol. In embodiments, the lubricating oil composition comprises more than 0.1 (such as 0.1 to 10, such as 0.5 to 8) mass %, functionalized (such as aminated) polybutene (such as polyisobutylene), such as PIBSA-PAM.

[0110] In embodiments, the lubricating oil composition may comprise 20 (such as 15, such as 10, such as 5, such as 3, such as 1) mass % or less block copolymer, such as block, star, random, and/or tapered block copolymer).

[0111] In embodiments, the lubricating oil composition may be substantially free of or may be absent block copolymer, such as block, star, random, and/or tapered block copolymer.

[0112] In embodiments, the lubricating oil composition may comprise 20 (such as 15, such as 10, such as 5, such as 3, such as 1) mass % or less styrenic copolymer, such as block, star, random, and/or tapered styrenic block copolymer).

[0113] In embodiments, the lubricating oil composition may be substantially free or absent styrenic copolymer, such as block, star, random, and/or tapered styrenic block copolymer.

[0114] In embodiments, the lubricating oil composition may comprise less than 20 (such as less than 15, such as less than 10, such as less than 5, such as less than 3, such as less than 1) mass % of functionalized diluent, such as functionalized oil.

[0115] In embodiments, the lubricating oil composition may comprise, may be substantially free of, or may be absent functionalized diluent, such as functionalized oil.

[0116] In embodiments, the lubricating oil composition may comprise less than 20 (such as less than 15, such as less than 10, such as less than 5, such as less than 3, such as less than 1) mass % of solvent, such as aromatic solvent.

[0117] In embodiments, the lubricating oil composition may be substantially free of or absent solvent, such as functionalized solvent.

[0118] In embodiments, the lubricating oil composition may have a total saponification number (SAP) of 25 (such as 28, such as 30, such as 32) mgKOH/g or more, as determined by ASTM 94.

[0119] In embodiments, the lubricating oil composition may have a total saponification number (SAP) of 25 (such as 28, such as 30, such as 32) mgKOH/g or more, as determined by ASTM 94 and the functionalized polymer has a Functionality Distribution (Fd) value of 3.5 or less (such as 3.4 or less, such as from 1 to 3.3, such as from 1.1 to 3.2, such as from 1.2 to 3.0, such as 1.4 to 2.9, as determined by GPC-PS as described in the Experimental section below).

[0120] In embodiments, the lubricating oil composition may have a total saponification number (SAP) of 25 (such as 28, such as 30, such as 32) mgKOH/g or more, as determined by ASTM 94 and the functionalized polymer has an average functionality of 1.4 to 20 FG grafts/polymer chain, such as 1.4 to 15 FG grafts/polymer chain, such as 3 to 12.5 FG grafts/polymer chain, such as 4 to 10 FG grafts/polymer chain, as determined by GPC-PS as described in the Experimental section below.

[0121] In embodiments, the lubricating oil composition may comprise less than 0.5 (such as 0.4, such as less than 0.3, such as less than 0.2, such as less than 0.1, substantially absent, or

zero) wt %, based upon the weight of the LOC, of secondary hydrocarbyl amine compounds and tertiary hydrocarbyl amine compounds.

[0122] In embodiments, the lubricating oil composition may be substantially absent, or may comprise no, secondary hydrocarbyl amine compounds and tertiary hydrocarbyl amine compounds.

[0123] In embodiments, the lubricating compositions of the present disclosure may be a heavy-duty diesel oil (*e.g.*, for use in an engine for a heavy-duty diesel vehicle, *i.e.*, a heavy-duty diesel vehicle having a gross vehicle weight rating of 10,000 pounds or more.)

[0124] In embodiments, the lubricating compositions of the present disclosure may be a passenger car motor oil.

[0125] In embodiments, the lubricating compositions of the present disclosure may be a passenger car diesel oil.

[0126] In embodiments, the lubricating composition of the present disclosure may be a diesel engine lubricating composition comprising: an oil of lubricating viscosity having greater than 50 wt % of Group I, II, III, IV, and/or V oil (such as a Group III base oil, a Group IV base oil, a Group V base oil, or mixtures thereof); a first PIB succinimide dispersant derived from an 1800 to 2500 Mn PIB; a second PIB succinimide dispersant derived from a PIB with an Mn less than 1600, where at least one of the first PIB succinimide dispersant(s) and the second PIB succinimide dispersant is boron-free (optionally, at least one of the first PIB succinimide dispersant(s) and the second PIB succinimide dispersant is borated); a amide, imide, and/or ester functionalized partially or fully saturated polymer comprising C₄₋₅ olefins as described herein; an alkaline earth metal salicylate detergent; an alkaline earth metal sulfonate detergent present in an amount to deliver 0.1 wt % to 1.2 wt % of alkaline earth metal soap to the lubricating composition; and a phosphorus anti wear agent present in an amount to deliver 300 to 900 ppm phosphorous to the lubricating composition, the lubricating composition having a total sulfated ash of between 0.3 to 1.1 wt %; a kinematic viscosity at 100° C of less than 8.3 cSt; a total alkaline earth metal soap of from 0.6 wt % to 2.1 wt %, and a HTHS150 measured according to ASTM D4683 of less than 2.7 mPa·s.

[0127] The lubricating compositions disclosed herein, such as diesel engine lubricating compositions, may have a kinematic viscosity as measured by ASTM D-445 at 100° C of from 2.5 to 8.3 (such as 2.5 to 6.5, or 3 to 5.5, or 3.5 to 6.5) cSt (mm²/s) and a kinematic viscosity at 40° C of from 15 to 30 (such as 15 to 25) cSt (mm²/s).

[0128] The lubricating composition disclosed herein, such as diesel engine lubricating compositions, may have a high temperature, high shear viscosity (HTHS) as measured by

ASTM D4683 at 150° C of less than 2.6 mPa·s, or less than 2.5 mPa·s, or less than 2.4 mPa·s, or less than 2.3 mPa·s, or less than 2.2 mPa·s, or less than 2.1 mPa·s. In another embodiment, the HTHS of the lubricating composition is from 1.4 to 2.5 mPa·s, or from 1.6 to 2.1 mPa·s, or from 1.8 to 2.1 mPa·s, or from 1.9 to 2.0 mPa·s.

[0129] The lubricating composition, such as diesel engine lubricating compositions, may have a SAE viscosity grade of 0W-Y, wherein Y may be 12, 16, or 20. In one embodiment, the lubricating composition has an SAE viscosity grade of 0W-12.

[0130] The lubricating compositions disclosed herein, such as diesel engine lubricating compositions, may have: 1) a kinematic viscosity as measured by ASTM D-445 at 100° C of from 2.5 to 8.3 (such as 2.5 to 6.5, or 3 to 5.5, or 3.5 to 6.5) cSt (mm²/s); 2) a high temperature, high shear viscosity (HTHS) as measured by ASTM D4683 at 150° C of less than 2.6 mPa·s, or less than 2.5 mPa·s, or less than 2.4 mPa·s, or less than 2.3 mPa·s, or less than 2.2 mPa·s, or less than 2.1 mPa·s (alternately from 1.4 to 2.5 mPa·s, or from 1.6 to 2.1 mPa·s, or from 1.8 to 2.1 mPa·s, or from 1.9 to 2.0 mPa·s); and
3) a SAE viscosity grade of 0W-Y, wherein Y may be 12, 16, or 20 (such as 0W-12).

Concentrates

[0131] A concentrate, also referred to as an additive package, adpak, or addpack, is a composition having less than 50 mass % (such as less than 40 mass %, such as less than 30 mass %, such as less than 25 mass %, such as less than 20 mass %) base oil and lubricant composition additives (such as described herein) which is typically then further blended with additional base oil to form a lubricating oil product.

[0132] This disclosure relates to concentrate compositions comprising or resulting from the admixing of:

- (a) from 1 to less than 50 mass % (alternately 5 to 45 mass %, alternately 7 to 40 mass %, alternately 10 to 35 mass %, alternately 10 to 25 mass %) of one or more base oils, based upon the weight of the lubricating composition;
- (b) from 0.10 to 20 mass % (in particular 0.2 to 15 mass %, alternately 0.5 mass % to 10 mass %, alternately 1 to 7 mass %), based upon the weight of the composition, of one or more amide, imide, and/or ester functionalized partially or fully saturated polymers comprising C₄₋₅ olefins having:
 - i) an Mw/Mn of less than 2,
 - ii) a Functionality Distribution (Fd) value of 3.5 or less (GPC-PS), and

iii) an Mn of 10,000 g/mol or more (GPC-PS) of the polymer prior to functionalization, provided that, if the polymer prior to functionalization is a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 g/mol (GPC-PS).

[0133] This disclosure relates to concentrate compositions comprising or resulting from the admixing of:

- (i) from 1 to less than 50 mass % (alternately 5 to 45 mass %, alternately 7 to 40 mass %, alternately 10 to 35 mass %, alternately 10 to 25 mass %), based upon the weight of the composition, of one or more base oil(s);
- (ii) from 0.10 to 20 mass % (in particular 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %), based upon the weight of the composition, of one or more detergent(s);
- (iii) from 0.10 to 20 mass % (in particular 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %), based upon the weight of the composition, of one or more dispersant(s) (such as PIBSA-PAM); and
- (iv) from 0.10 to 20 mass % (in particular 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 2 mass %), based upon the weight of the composition, of one or more functionalized amide, imide, and/or ester functionalized partially or fully saturated polymers described herein;
- (v) optional additional components, antioxidants, pour point depressants, anti-foam agents, viscosity modifiers, corrosion inhibitors, antiwear agents, extreme pressure additives, demulsifiers, seal compatibility agents, additive diluent base oils, friction modifier(s) (such as, organic FM, such as organic ester, such as fatty acid ester), etc.

[0134] In embodiments, the concentrate composition may optionally be absent solvent (such as aliphatic or aromatic solvent) and/or absent functionalized base oil.

[0135] This disclosure also relates to concentrate compositions comprising or resulting from the admixing of:

- A) from 1 to less than 50 mass % (alternately 5 to 45 mass %, alternately 7 to 40 mass %, alternately 10 to 35 mass %, alternately 10 to 25 mass %), based upon the weight of the concentrate composition, of one or more base oil(s);
- B) from 0.10 to 20 mass % (in particular, 0.15 to 10 mass %, alternately 0.20 mass % to 5 mass %, alternately 0.25 to 3 mass %), based upon the weight of the concentrate composition, of one or more functionalized polymers having:
 - a) an Mw/Mn of less than 2 (such as less than 1.6, such as less than 1.5, such as from 1 to 1.3, such as from 1.0 to 1.25 as determined by GPC-PS),

b) a Functionality Distribution (Fd) value of 3.5 or less (such as 3.4 or less, such as from 1 to 3.3, such as from 1.1 to 3.2, such as from 1.2 to 3.0, such as 1.4 to 2.9, as determined by GPC-PS), and

wherein the polymer prior to functionalization has an Mn of 25,000 g/mol (such as 30,000 g/mol) or more (GPC-PS);

C) from 0.1 to 20 wt % (in particular 0.5 to 10 mass %, alternately 2 to 6 mass %), based on total weight of the concentrate composition, of one or more detergent(s) (such as blends of detergents);

D) optionally, from 0.01 to 5 wt % (in particular, 0.1 to 4 mass %, alternately 0.25 to 3 mass %, alternately 0.25 to .075 mass %), based on total weight of the concentrate composition, of one or more friction modifier(s) (such as organic friction modifiers, such as glycerol monooleate);

E) optionally, from 0.01 to 20 wt % (in particular, 0.01 to 15 mass %, alternately 0.1 to 10 mass %), based on total weight of the concentrate composition, of one or more antioxidant(s) (such as blends of antioxidants);

F) optionally, from 0.01 to 5 wt % (in particular, 0.01 to 3 mass %, alternately 0.1 to 1.5 mass %), based on total weight of the concentrate composition, of one or more pour point depressants (such as blends of pour point depressants);

G) optionally, from 0.001 to 5 wt % (in particular, 0.01 to 3 mass %, alternately 0.02 to 1 mass %), based on total weight of the concentrate composition, of one or more anti-foam agents (such as blends of anti-foam agents);

I) optionally, from 0.01 to 40 wt % (in particular, 0.1 to 30 mass %, alternately 1 to 20 mass %), based on total weight of the concentrate composition, of one or more dispersants (such as blends of dispersants);

K) optionally, from 0.001 to 10 wt % (in particular, 0.1 to 8 mass %, alternately 1 to 5 mass % alternately 0.25 to .075 mass %), based on total weight of the lubricating composition, of one or more antiwear agents (such as blends of antiwear agents, such as ZDDP).

[0136] Optionally, the concentrate may be absent functionalized oil.

[0137] In embodiments, the concentrate composition may optionally be absent solvent (such as aliphatic or aromatic solvent) and/or absent functionalized base oil.

[0138] Optionally, the concentrate may be absent phenolic antioxidant.

[0139] In embodiments, the concentrate may comprise less than 75 ppm boron, alternately less than 60 ppm boron, alternately from 1 to 70 ppm boron. Alternately, the concentrate may be absent boron.

[0140] In embodiments, the concentrate may comprise less than 20 (such as 15, such as 10, such as 5, such as 3, such as 1) mass %, functionalized (such as aminated) polybutene (such as polyisobutylene), such as PIBSA-PAM. In embodiments, the concentrate comprises is substantially free or absent, functionalized (such as aminated) polybutene (such as polyisobutylene), such as PIBSA-PAM.

[0141] In embodiments, the concentrate may comprise acylated polymers, such as polyisobutylene succinic acid, optionally, having an Mn of 500 to 50,000 g/mol, such as 600 to 5,000 g/mol, such as 700 to 3000 g/mol. In embodiments, the concentrate may comprise acylated polymers, such as polyisobutylene succinic acid, having an Mn of 500 1600 g/mol, such as 700 to 1200 g/mol.

[0142] In embodiments, the concentrate may comprise 20 (such as 15, such as 10, such as 5, such as 3, such as 1) mass % or less block copolymer, such as block, star, random, and/or tapered block copolymer.

[0143] In embodiments, the concentrate may be substantially free of or absent block copolymer, such as block, star, random, and/or tapered block copolymer.

[0144] In embodiments, the concentrate may comprise 20 mass % or less (such as 15 mass % or less, such as 10 mass % or less, such as 5 mass % or less, such as 3 mass % or less, such as 1) mass % or less styrenic copolymer, such as block, star, random, and/or tapered styrenic block copolymer).

[0145] In embodiments, the concentrate may be substantially free of or absent styrenic copolymer, such as block, star, random, and/or tapered styrenic block copolymer).

[0146] In embodiments, the concentrate may comprise less than 20 (such as less than 15, such as 10, such as less than 5, such as less than 3, such as 1) mass % of functionalized diluent, such as functionalized oil.

[0147] In embodiments, the concentrate may substantially free of or absent functionalized diluent, such as functionalized oil.

[0148] In embodiments, the concentrate may comprise less than 0.5 (such as less than 0.4, such as less than 0.3, such as less than 0.2, such as 0.1, substantially absent, no) wt %, based upon the weight of the concentrate, of secondary hydrocarbyl amine compounds and tertiary hydrocarbyl amine compounds.

[0149] In embodiments, the concentrate may be substantially absent, or may comprise no, secondary hydrocarbyl amine compounds and tertiary hydrocarbyl amine compounds.

[0150] In embodiments, the concentrate may have a kinematic viscosity at 100° C of less than 1000 cSt, such as less than 500 cSt, such as less than 200 cSt.

A. Base Oil

[0151] The base oil (also referred to as "base stock," "lubricating oil basestock," or "oil of lubricating viscosity") useful herein may be a single oil or a blend of oils, and is typically a large liquid constituent of a lubricating composition, also referred to as a lubricant, into which additives and optional additional oils are blended, for example, to produce a lubricating composition, such as a final lubricant composition, a concentrate, or other lubricating composition.

[0152] A base oil may be selected from vegetable, animal, mineral, and synthetic lubricating oils, and mixtures thereof. It may range in viscosity from light distillate mineral oils to heavy lubricating oils, such as those for gas engine oil, mineral lubricating oil, motor vehicle oil, and heavy-duty diesel oil. Generally, the kinematic viscosity at 100° C ("KV100") of the base oil ranges from 1 to 30, such as 2 to 25 cSt, such as 5 to 20 cSt, as determined according to ASTM D445-19a, in particular, from 1.0 cSt to 10 cSt, from 1.5 cSt to 3.3 cSt, from 2.7 cSt to 8.1 cSt, from 3.0 cSt to 7.2 cSt, or from 2.5 cSt to 6.5 cSt. Generally, the high temperature high shear (HTHS) viscosity at 150° C of the base oil ranges from 0.5 to 20 cP such as 1 to 10 cP, such as 2 to 5 cP as determined according to ASTM D4683-20.

[0153] Typically, when lubricating oil basestock(s) is used to make a concentrate, it may advantageously be present in a concentrate-forming amount to give a concentrate containing, from 5 wt % to 80 wt %, from 10 wt % to 70 wt %, or from 5 wt % to 50 wt % of active ingredient, based upon the weight of the concentrate.

[0154] Common oils useful as base oils include animal and vegetable oils (*e.g.*, castor and lard oil), liquid petroleum oils, and hydrotreated and/or solvent-treated mineral lubricating oils of the paraffinic, naphthenic, and mixed paraffinic-naphthenic types. Oils derived from coal or shale are also useful base oils. Base stocks may be manufactured using a variety of different processes including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and re-refining.

[0155] Synthetic lubricating oils useful herein as base oils include hydrocarbon oils such as homopolymerized and copolymerized olefins, referred to as polyalphaolefins or PAO's or group IV base oils [according to the API EOLCS 1509 definition (American Petroleum Institute Publication 1509, see section E.1.3, 19th edition, January 2021, www.API.org)].

Examples of PAO's useful as base oils include: poly(ethylenes), copolymers of ethylene and propylene, polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes), homo- or co-polymers of C₈ to C₂₀ alkenes, homo- or co-polymers of C₈, and/or C₁₀, and/or C₁₂ alkenes, C₈/C₁₀ copolymers, C₈/C₁₀/C₁₂ copolymers, and C₁₀/C₁₂ copolymers, and the derivatives, analogues and homologues thereof.

[0156] In another embodiment, the base oil may comprise polyalphaolefins comprising oligomers of linear olefins having 6 to 14 carbon atoms, more preferably 8 to 12 carbon atoms, more preferably 10 carbon atoms having a Kinematic viscosity at 100° C of 10 or more (as measured by ASTM D445); and preferably having a viscosity index ("VI"), as determined by ASTM D2270, of 100 or more, preferably 110 or more, more preferably 120 or more, more preferably 130 or more, more preferably 140 or more; and/or having a pour point of -5° C or less (as determined by ASTM D97), more preferably -10° C or less, more preferably -20° C or less.

[0157] In another embodiment polyalphaolefin oligomers useful in the present disclosure may comprise C₂₀ to C₁₅₀₀ paraffins, preferably C₄₀ to C₁₀₀₀ paraffins, preferably C₅₀ to C₇₅₀ paraffins, preferably C₅₀ to C₅₀₀ paraffins. The PAO oligomers are dimers, trimers, tetramers, pentamers, *etc.*, of C₅ to C₁₄ alpha-olefins in one embodiment, and C₆ to C₁₂ alpha-olefins in another embodiment, and C₈ to C₁₂ alpha-olefins in another embodiment. Suitable olefins include 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene, 1-undecene, and 1-dodecene. In one embodiment, the olefin is a combination of 1-octene, 1-decene, and 1-dodecene, or alternately may be substantially 1-decene, and the PAO is a mixture of dimers, trimers, tetramers, and pentamers (and higher) thereof. Useful PAO's are described more particularly in, for example, US Patent Nos. 5,171,908 and 5,783,531, and in *Synthetic Lubricants and High-Performance Functional Fluids 1-52* (Leslie R. Rudnick & Ronald L. Shubkin, ed. Marcel Dekker, Inc. 1999).

[0158] PAO's useful in the present disclosure typically possess a number average molecular weight of from 100 to 21,000 g/mol in one embodiment, and from 200 to 10,000 g/mol in another embodiment, and from 200 to 7,000 g/mol in yet another embodiment, and from 200 to 2,000 g/mol in yet another embodiment, and from 200 to 500 g/mol in yet another embodiment. Desirable PAO's are commercially available as SpectraSyn™ Hi-Vis, SpectraSyn™ Low-Vis, SpectraSyn™ plus, SpectraSyn™ Elite PAO's (ExxonMobil Chemical Company, Houston Texas) and Durasyn PAO's from Ineos Oligomers USA LLC.

[0159] Synthetic lubricating oils useful as base oils also include hydrocarbon oils such as homopolymerized and copolymerized: 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 homologues thereof.

[0160] Another suitable class of synthetic lubricating oils useful as base oils comprises the esters of dicarboxylic acids (*e.g.*, phthalic acid, succinic acid, alkyl succinic acids and alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkylmalonic acids, alkenyl malonic acids) reacted with a variety of alcohols (*e.g.*, 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 two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid.

[0161] Esters useful as synthetic oils herein also include those made from C₅ to C₁₂ monocarboxylic acids and polyols, and polyol ethers such as neopentyl glycol, trimethylolpropane, pentaerythritol, dipentaerythritol, and tripentaerythritol.

[0162] Desirable ester base oils are commercially available as Esterex™ Esters (ExxonMobil Chemical Company, Houston, Texas).

[0163] Silicon-based oils such as the polyalkyl-, polyaryl-, polyalkoxy- or polyaryloxysilicone oils and silicate oils comprise another useful class of synthetic lubricants useful herein; such oils include tetraethyl silicate, tetraisopropyl silicate, tetra-(2-ethylhexyl) silicate, tetra-(4-methyl-2-ethylhexyl)silicate, tetra-(p-tert-butyl-phenyl) silicate, hexa-(4-methyl-2-ethylhexyl)disiloxane, poly(methyl)siloxanes, and poly(methylphenyl)-siloxanes.

[0164] Other synthetic lubricating oils useful herein include liquid esters of phosphorous-containing acids (*e.g.*, tricresyl phosphate, trioctyl phosphate, diethyl ester of decylphosphonic acid) and polymeric tetrahydrofurans.

[0165] Unrefined, refined, and re-refined oils can be used in the lubricating compositions of the present disclosure. 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 an ester oil obtained directly from an esterification process and used without further treatment is considered an

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 used by those in the art. Re-refined oils are oils obtained by processes similar to those used to obtain refined oils where the refining processes are applied to previously refined oils which have been previously used in service. Such re-refined oils are also referred to as reclaimed or reprocessed oils and often are additionally processed for removal of spent additive and oil breakdown products. A re-refined base oil is preferably substantially free from materials introduced through manufacturing, contamination, or previous use.

[0166] Other examples of useful base oils are gas-to-liquid ("GTL") base oils, *i.e.*, the base oil is an oil derived from hydrocarbons made from synthesis gas ("syn gas") containing H₂ and CO using a Fischer-Tropsch catalyst. These hydrocarbons typically require further processing in order to be useful as a base oil. For example, they may, by methods known in the art, be hydroisomerized; hydrocracked and hydroisomerized; dewaxed; or hydroisomerized and dewaxed. For further information on useful GTL base oils and blends thereof, please see US Patent No. 10,913,916 (col 4, ln 62 to col 5, ln 60) and US Patent No. 10,781,397 (col 14, ln 54 to col 15, ln 5, and col 16, ln 44 to col 17, ln 55).

[0167] In particular, oils from renewable sources, *i.e.*, based in part on carbon and energy captured from the environment, such as biological sources, are useful herein.

[0168] The various base oils are often categorized as Group I, II, III, IV, or V according to the API EOLCS 1509 definition (American Petroleum Institute Publication 1509, see section E.1.3, 19th edition, January 2021, www.API.org). Generally speaking, Group I base stocks have a viscosity index of between about 80 to 120 and contain greater than about 0.03 % sulfur and/or less than about 90 % saturates. Group II base stocks have a viscosity index of between about 80 to 120 and contain less than or equal to about 0.03 % sulfur and greater than or equal to about 90 % saturates. Group III base stocks have a viscosity index greater than about 120 and contain less than or equal to about 0.03 % sulfur and greater than about 90 % saturates. Group IV base stocks includes polyalphaolefins (PAO). Group V base stocks include base stocks not included in Groups I-IV. (Viscosity index measured by ASTM D 2270, saturates is measured by ASTM D2007, and sulfur is measured by ASTM D5185, D2622, ASTM D4294, ASTM D4927, and ASTM D3120).

[0169] Base oils for use in the formulated lubricating compositions useful in the present disclosure are any one, two, three, or more of the variety of oils described herein. In desirable embodiments, base oils for use in the formulated lubricating compositions useful in the present

disclosure are those described as API Group I, Group II, Group III (including Group III+), Group IV, and Group V oils and mixtures thereof, preferably API Group II, Group III, Group IV, and Group V oils and mixtures thereof, more preferably the Group III, Group III+, IV, and Group V base oils due to their exceptional volatility, stability, viscometric, and cleanliness features. Minor quantities of Group I basestock, such as the amount used to dilute additives for blending into formulated lube oil products, can be tolerated but are typically kept to a minimum, *e.g.*, amounts only associated with their use as diluent/carrier oil for additives used on an "as-received" basis. In regard to the Group II stocks, it is more useful that the Group II base stock be in the higher quality range associated with that stock, *i.e.*, a Group II stock having a viscosity index in the range from 100 to 120.

[0170] The base oil useful herein may be selected from any of the synthetic, natural, or re-refined oils (such as those typically used as crankcase lubricating oils for spark-ignited and compression-ignited engines). Mixtures of synthetic and/or natural and/or re-refined base oils may be used if desired. Multi-modal mixtures (such as bi- or tri-modal mixtures) of Group I, II, III, IV, and/or V base stocks may be used if desired.

[0171] The base oil or base oil blend used herein conveniently has a kinematic viscosity at 100° C (KV100, as measured according to ASTM D445-19a, and reported in units of centistoke (cSt) or its equivalent, mm²/s), of about 2 to about 40 cSt, alternately of 3 to 30 cSt, alternately 4 to 20 cSt at 100° C, alternately 5 to 10 cSt, alternately the base oil or base oil blend may have a kinematic viscosity at 100° C of 2 to 20 cSt, of 2.5 to 2 cSt, and preferably of about 2.5 cSt to about 9 cSt.

[0172] The base oil or base oil blend preferably has a saturate content of at least 65 mass %, more preferably at least 75 mass %, such as at least 85 mass %, such as at least 90 mass % as determined by ASTM D2007.

[0173] Preferably, the base oil or base oil blend will have a sulfur content of less than 1 mass %, preferably less than 0.6 mass %, most preferably less than 0.4 mass %, such as less than 0.3 mass %, based on the total mass of the lubricating composition, as measured by ASTM D5185.

[0174] In embodiments, the volatility of the base oil or base oil blend, as measured by the Noack test (ASTM D5800, procedure B), is less than or equal to 30 mass %, such as less than or equal to 25 mass %, such as less than or equal to 20 mass %, such as less than or equal to 16 mass %, such as less than or equal to 12 mass %, such as less than or equal to 10 mass %, based on the total mass of the lubricating composition.

[0175] In embodiments, the viscosity index (VI) of the base oil is at least 95, preferably at least 110, more preferably at least 120, even more preferably at least 125, most preferably from about 130 to 240, in particular from about 105 to 140 (as determined by ASTM D2270).

[0176] The base oil may be provided in a major amount, in combination with a minor amount of one or more additive components as described hereinafter, constituting a lubricant. This preparation may be accomplished by adding the additives directly to the oil or by adding the one or more additives in the form of a concentrate thereof to disperse or dissolve the additive(s). Additives may be added to the oil by any method known to those skilled in the art, either before, at the same time as, or after addition of other additives.

[0177] The base oil may be provided in a minor amount, in combination with minor amounts of one or more additive components as described hereinafter, constituting an additive concentrate. This preparation may be accomplished by adding the additives directly to the oil or by adding the one or more additives in the form of a solution, slurry or suspension thereof to disperse or dissolve the additive(s) in the oil. Additives may be added to the oil by any method known to those skilled in the art, either before, at the same time as, or after addition of other additives.

[0178] The base oil typically constitutes the major component of an engine oil lubricant composition of the present disclosure and typically is present in an amount ranging from about 50 to about 99 wt %, preferably from about 70 to about 95 wt %, and more preferably from about 80 to about 95 wt %, based on the total weight of the composition.

[0179] Typically, one or more base oils are present in the lubricating composition in an amount of 32 wt % or more, alternately 55 wt % or more, alternately 60 wt % or more, alternately 65 wt % or more, based on the total weight of the lubricating composition. Typically, one or more base oils are present in the lubricating composition at an amount of 98 wt % or less, more preferably 95 wt % or less, even more preferably 90 wt % or less. Alternately, one or more base oils are present in the lubricating composition at from 1 to 99 mass %, alternately 50 to 97 mass %, alternately to 60 to 95 mass %, alternately 70 to 95 mass %, based upon the weight of the lubricating composition.

[0180] The base oils and blends thereof described above are also useful for making concentrates as well as for making lubricants therefrom.

[0181] Concentrates constitute a convenient means of handling additives before their use, as well as facilitating solution or dispersion of additives in lubricants. When preparing a lubricant that contains more than one type of additive (sometime referred to as "additive components"), each additive may be incorporated separately, each in the form of a concentrate.

In many instances, however, it is convenient to provide a so-called additive "package" (also referred to as an "addpack") comprising one or more additives/co-additives, such as described hereinafter, in a single concentrate.

[0182] Typically, one or more base oils are present in the concentrate composition in an amount of 50 wt % or less, alternately 40 wt % or less, alternately 30 wt % or less, alternately 20 wt % or less, based on the total weight of the concentrate composition. Typically, one or more base oils are present in the concentrate composition at an amount of 0.1 to 49 mass %, alternately 5 to 40 mass %, alternately 10 to 30 mass %, alternately 15 to 25 mass %, based upon the weight of the concentrate composition.

[0183] In embodiments, the acylation/functionalization reactions described herein may take place in the presence of base oil diluent. As a side product, functionalized base oil can be produced. The oil may become acylated and/or functionalized itself. For example, maleated base oil or aminated base oil may be present after the functionalization reactions described herein.

[0184] It is contemplated that the functionalized base oil may comprise the acylated oil.

[0185] It is contemplated that the functionalized base oil may comprise the reaction product of the acylated oil with an amine to form an amide, imide or combination thereof.

[0186] It is contemplated that the functionalized base oil may comprise both acylated oil and reaction product of the acylated oil with an amine to form an amide, imide or combination thereof.

[0187] In embodiments the lubricating oil composition and/or concentrate compositions may comprise functionalized base oil, such as acylated oil and/or reaction product of the acylated oil with an amine or alcohol to form an amide, imide, ester, or combination thereof, in an amount of 40 wt % or less, alternately 20 wt % or less, alternately 10 wt % or less, alternately 5 wt % or less, based on the total weight of the concentrate composition. Typically, one or more functionalized base oil, such as acylated oil and/or reaction product of the acylated oil with an amine or alcohol to form an amide, imide, ester, or combination thereof, are present in the concentrate at an amount of 0.01 to 40 mass %, alternately 0.1 to 20 mass %, alternately 1 to 10 mass %, alternately 1.5 to 5 mass %, based upon the weight of the concentrate composition.

[0188] Typically, one or more functionalized base oil, such as acylated oil and/or reaction product of the acylated oil with an amine or alcohol to form an amide, imide, ester, or combination thereof, are present in the lubricating oil composition at an amount of 0.01 to 40

mass %, alternately 0.1 to 20 mass %, alternately to 1 to 10 mass %, alternately 1.5 to 5 mass %, based upon the weight of the lubricating oil composition.

[0189] In embodiments, functionalized oil may be present in a lubricating oil composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the lubricating oil composition.

[0190] In embodiments, functionalized oil may be present in a concentrate composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the concentrate composition.

[0191] In embodiments, the acylation/functionalization reactions described herein may take place in solvent-containing media. As a side product, functionalized solvent can be produced. The solvent may become acylated and/or functionalized itself. In embodiments, acylated and/or functionalized solvent may be present in a concentrate composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the concentrate composition. In embodiments, functionalized solvent may be present in a lubricating oil composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the lubricating oil composition.

B. Functionalized Polymer

[0192] This disclosure relates to a functionalized polymer comprising a polymer that prior to functionalization has an Mn of about 10,000 g/mol or more, such as 20,000 g/mol or more, such as 25,000 g/mol or more, such as 30,000 g/mol or more, such as 35,000 g/mol or more (GPC-PS). Alternately, functionalized polymer comprises a polymer that prior to functionalization has an Mn of 10,000 to 300,000 g/mol, such as 20,000 to about 150,000 g/mol, such as 30,000 to about 125,000 g/mol, such as 35,000 to about 100,000 g/mol, such as 40,000 to 80,000 g/mol (GPC-PS). The polymer prior to functionalization may have an Mw/Mn of less than 2 (such as less than 1.6, such as less than 1.5, such as 1.4 or less, such as from 1 to 1.3, such as from 1.0 to 1.25, such as from 1.0 to 1.2, such as 1.0 to 1.15, such as from 1.0 to 1.1 as determined by GPC-PS). The polymer prior to functionalization may comprise repeat units of one or more olefins having 4 to 5 carbon atoms (preferably conjugated dienes having 4 to 5 carbon atoms). Prior to functionalization the C₄₋₅ polymer is preferably fully or partially saturated (such as fully or partially hydrogenated). The functionalized polymer may be obtained by reacting the C₄₋₅ polymer with an acylating agent to form acylated polymer and then reacting acylated polymer with an amine or alcohol to form an amide, imide, ester, or

combination thereof. The functionalized polymer may also be obtained by reacting an acylated C₄₋₅ polymer (such as a commercially available maleated fully or partially hydrogenated C₄₋₅ polymer) with an amine to form an amide, imide or combination thereof.

[0193] This disclosure further relates to amide, imide, and/or ester functionalized saturated (such as hydrogenated) polymers of C₄₋₅ conjugated dienes described herein obtained by reacting fully or partially saturated (such as fully or partially hydrogenated) polymers of C₄₋₅ conjugated dienes having an Mw/Mn of less than 2, with an acylating agent, such as maleic acid or maleic anhydride and thereafter reacting the acylated polymer with an amine (such as a polyamine) to form an imide, amide or combination thereof.

[0194] This disclosure relates to polymers containing one or more pendant amine groups and comprising or resulting from the admixing of: at least partially (preferably completely) hydrogenated C₄₋₅ olefin polymers with an acylating agent, such as maleic acid or maleic anhydride, and thereafter reacting the acylated polymer with a polyamine to form an imide, amide or combination thereof.

[0195] In embodiments, the functionalized polymer is not prepared in aromatic solvent (such as benzene or toluene), or aromatic solvent is present at 2 wt % or less (such as 1 wt % or less, such as 0.5 wt % or less), based upon the weight of solvent, diluent, and polymer.

[0196] In embodiments, the functionalized polymer is not prepared in an alkylated naphthylenic solvent, or alkylated naphthylenic solvent is present at 5 wt % or less (such as 3 wt % or less, such as 1 wt % or less), based upon the weight of solvent, diluent, and polymer.

[0197] The polymer useful herein to prepare the functionalized polymer may be a homopolymer of butadiene, isoprene, or the like.

[0198] In embodiments, the polymer useful herein to prepare the functionalized polymer may be a homopolymer of isoprene, or a copolymer of isoprene and less than 5 mol % (such as less than 3 mol %, such as less than 1 mol %, such as less than 0.1 mol %) comonomer.

[0199] The polymer useful herein to prepare the functionalized polymer may be copolymer of isoprene and one or more of styrene, methyl-styrene, 2,3-dimethyl-butadiene, 2-methyl-1,3-pentadiene, myrcene, 3-methyl-1,3-pentadiene, 4-methyl-1,3-pentadiene, 2-phenyl-1,3-butadiene, 2-phenyl-1,3-pentadiene, 3-phenyl-1,3-pentadiene, 2,3-dimethyl-1,3-pentadiene, 2-hexyl-1,3-butadiene, 3-methyl-1,3-hexadiene, 2-benzyl-1,3-butadiene, 2-p-tolyl-1,3-butadiene, 1,3-butadiene, 1,3-pentadiene, 1,3-hexadiene, 1,3-heptadiene, 2,4-heptadiene, 1,3-octadiene, 2,4-octadiene, 3,5-octadiene, 1,3-nonadiene, 2,4-nonadiene, 3,5-nonadiene, 1,3-decadiene, 2,4-decadiene, and 3,5-decadiene, [optionally the comonomer(s) are present at less than 20

mol %, less than 5 mol %, such as less than 3 mol %, such as less than 1 mol %, such as less than 0.1 mol %].

[0200] Generally, the polymerized conjugated diene polymer useful herein to prepare the functionalized polymer includes a mixture of 1,4- and 1,2-insertions (*a.k.a.* 2,1-insertions; for butadiene, 1,2-insertions are the same as 3,4-insertions). As measured by ¹H NMR, the polymerized conjugated diene polymer useful herein to prepare the functionalized polymer contains at least about 50 % of 1,4-insertions, such as at least about 75 % of 1,4 insertions, such as at least about 80 % of 1,4 insertions, such as at least about 90 % of 1,4 insertions, such as at least about 95 % of 1,4 insertions, such as at least 98 % of 1,4 insertions, based upon the total of the 2,1 insertions, 1,4 insertions, and 3,4 insertions of isoprene. For purposes of this disclosure: 1) the phrase "1,4 insertion" includes 1,4 and 4,1 insertions, 2) the phrase "2,1 insertion" includes 2,1 and 1,2 insertions, and 3) the phrase "3,4 insertion" includes 3,4 and 4,3 insertions.

[0201] Optionally, styrene repeat units may be absent in the polymer useful herein to prepare the functionalized polymer. Optionally, styrene repeat units may be absent in the functionalized hydrogenated/saturated polymers.

[0202] Optionally, butadiene repeat units may be absent in the polymer useful herein to prepare the functionalized polymer. Optionally, butadiene repeat units may be absent in the functionalized hydrogenated/saturated polymers.

[0203] Optionally, the polymer useful herein to prepare the functionalized polymer may be not homopolybutylene. Optionally, the functionalized hydrogenated/saturated polymer may be not homopolybutylene.

[0204] Optionally, the polymer useful herein to prepare the functionalized polymer may be not homopolyisobutylene. Optionally, the functionalized hydrogenated/saturated polymer may be not homopolyisobutylene.

[0205] Optionally, the polymer useful herein to prepare the functionalized polymer may not be a copolymer of isoprene and butadiene. Optionally, the functionalized hydrogenated/saturated polymer may not be a copolymer of isoprene and butadiene.

[0206] The polymer useful herein to prepare the functionalized polymer and/or the functionalized polymer may be homopolymer or copolymer. The copolymer may be a random copolymer, a tapered block copolymer, a star copolymer, or a block copolymer. Block copolymers are formed from a monomer mixture comprising one or more first monomers (such as isobutylene), wherein, for example, a first monomer forms a discrete block of the polymer joined to a second discrete block of the polymer formed from a second monomer (such as

butadiene). While block copolymers have substantially discrete blocks formed from the monomers, a tapered block copolymer may be composed of, at one end, a relatively pure first monomer and, at the other end, a relatively pure second monomer. The middle of the tapered block copolymer may be more of a gradient composition of the two monomers.

[0207] The polymer useful herein to prepare the functionalized polymer may typically have an Mn of 20,000 to 150,000 g/mol, alternately 20,000 to about 150,000 g/mol, alternately 30,000 to about 125,000 g/mol, alternately 35,000 to about 100,000 g/mol, alternately 40,000 to 80,000 g/mol (GPC-PS).

[0208] Polymers useful herein to prepare the functionalized polymers may typically have an Mw/Mn (as determined by GPC-PS) of 1 to 2, alternately greater than 1 to less than 2, alternately 1.1 to 1.8, alternately 1.2 to 1.5. Alternately, the polymers useful herein to prepare the functionalized polymers may typically have an Mw/Mn of 1 or greater than 1 to less than 2 (such as less than 1.8, such as less than 1.7, such as less than 1.6, such as less than 1.5, such as less than 1.4, such as less than 1.3, such as less than 1.2, such as less than 1.15, such as less than 1.12, such as less than 1.10).

[0209] The polymers used to prepare the functionalized polymers may have an Mz (as determined by GPC-PS) of 20,000 to 150,000 g/mol, alternately 20,000 to about 150,000 g/mol, alternately 30,000 to about 125,000 g/mol, alternately 35,000 to about 100,000 g/mol, alternately 40,000 to 80,000 g/mol, alternately 40,000 to 60,000 g/mol (GPC-PS).

[0210] Polymers useful herein to prepare the functionalized polymers may have a glass transition temperature (Tg) of -25° C or less, such as -40° C or less, such as -50° C or less, as determined by Differential Scanning calorimetry (DSC) using a Perkin Elmer or TA Instrument Thermal Analysis System (sample is heated from ambient to 210° C at 10° C/minute and held at 210° C for 5 minutes, then cooled down to -40° C at 10° C/minute and held for 5 minutes.)

[0211] Polymers useful herein to prepare the functionalized polymers typically have a residual unsaturation of less than 3 %, such less than 2 %, such less than 1 %, such as less than 0.5 %, such as less than 0.25 % based upon number of double bonds in the non-hydrogenated polymer.

[0212] Polymers useful herein to prepare the functionalized polymers typically have a residual metal (such as Li, Co, and Al) content of less than 100 ppm, such less than 50 ppm, such as less than 25 ppm, such as less than 10 ppm, such as less than 5 ppm.

Hydrogenation

[0213] The C₄₋₅ polymer useful herein to prepare the functionalized polymer can be hydrogenated partially or completely by any hydrogenating agent known to one of ordinary

skill in the art. For example, a saturated or partially saturated polymer can be prepared by (a) providing a C₄₋₅ polymer containing unsaturations (such as double or triple bonds); and (b) hydrogenating at least a portion or all of the unsaturations (such as double or triple bonds) in the polymer in the presence of a hydrogenation reagent. In some embodiments, the polymer is fully hydrogenated. In some embodiments, the polymer is partially hydrogenated. In some embodiments, the polymer is saturated (hydrogenated) at 50 % or more, such as 60 % or more, such as 70 % or more, such as 80 % or more, such as 90 % or more, such as 95 % or more, such as 98 % or more, such as 99 % or more, such as from 50 to 100 % saturated (hydrogenated), as determined by ozone adsorption method described in Martino N. Smits and Dirkman Hoefman, Quantative Determination of Olefinic Unsaturation by Measurement of Ozone Absorption Analytical Chemistry Vol 44, No. 9, pg. 1688, 1972, Martino N. Smits.

[0214] In embodiments, the hydrogenation reagent can be hydrogen in the presence of a hydrogenation catalyst. In some embodiments, the hydrogenation catalyst is Pd, Pd/C, Pt, PtO₂, Ru(PPh₃)₂Cl₂, Raney nickel, or a combination thereof. In embodiments, the catalyst is a Pd catalyst. In another embodiment, the catalyst is 5 % Pd/C. In a further embodiment, the catalyst may comprise or be 10 % Pd/C in a high-pressure reaction vessel and the hydrogenation reaction is allowed to proceed until completion. Generally, after completion, the reaction mixture can be washed, concentrated, and dried to yield the corresponding hydrogenated product. Alternatively, any reducing agent that can reduce a C=C bond to a C—C bond can also be used. For example, the olefin polymer can be hydrogenated by treatment with hydrazine in the presence of a catalyst, such as 5-ethyl-3-methylflavinium perchlorate, under an oxygen atmosphere to give the corresponding hydrogenated products. The reduction reaction with hydrazine is disclosed in Imada et al., J Am. Chem. Soc., 127, pp. 14544-14545, (2005), which is incorporated herein by reference.

Acylation

[0215] The fully or partially saturated (hydrogenated) polymer may be chemically modified (functionalized) to provide a polymer having at least one polar functional group, such as, but not limited to, halogen, epoxy, hydroxy, amino, nitrilo, mercapto, imido, carboxy, and sulfonic acid groups or combinations thereof. The functionalized polymers can be further modified to give a more desired type of functionality. In a preferred case, the fully or partially hydrogenated polymer is functionalized by a method, which includes reacting the fully or partially hydrogenated polymer with an unsaturated carboxylic acid (or derivative thereof, such as maleic anhydride) to provide an acylated polymer (which may then be further functionalized as described below).

[0216] In some embodiments, a carboxylic acid functionality or a reactive equivalent thereof is grafted onto the polymer to form an acylated polymer. An ethylenically unsaturated carboxylic acid material is typically grafted onto the polymer backbone. These materials which are attached to the polymer typically contain at least one ethylenic bond (prior to reaction) and at least one, such as two, carboxylic acid (or its anhydride) groups or a polar group which is convertible into said carboxyl groups by oxidation or hydrolysis. Maleic anhydride or a derivative thereof is suitable. It grafts onto the polymer, to give two carboxylic acid functionalities. Examples of additional unsaturated carboxylic materials include itaconic anhydride, or the corresponding dicarboxylic acids, such as maleic acid, fumaric acid and their esters, as well as cinnamic acid and esters thereof.

[0217] The ethylenically unsaturated carboxylic acid material may be grafted onto the polymer in a number of ways. It may be grafted onto the polymer in solution or in essentially pure (molten) form with or without using a radical initiator. Free-radical induced grafting of ethylenically unsaturated carboxylic acid materials may also be conducted in solvents, such as hexane or mineral oil. It may be carried out at an elevated temperature in the range of 100° C to 250° C, *e.g.*, 120° C to 190° C, or 150° C to 180° C, *e.g.*, above 160° C.

[0218] The free-radical initiators which may be used include peroxides, hydroperoxides, and azo compounds, typically those which have a boiling point greater than about 100° C and which decompose thermally within the grafting temperature range to provide free radicals. Representative of these free-radical initiators include azobisisobutyronitrile and 2,5-dimethyl-hex-3-yne-2,5-bis-tertiary-butyl peroxide. The initiator may be used in an amount of 0.005 % to 1 % by weight based on the weight of the reaction mixture solution. The grafting may be carried out in an inert atmosphere, such as under nitrogen blanketing. The resulting acylated polymer intermediate is characterized by having carboxylic acid acylating functions as a part of its structure.

[0219] In embodiments, the acylated polymer may have 2 or more anhydride groups per polymer molecule and may exhibit less than 10 % gel. Alternately, the acylated polymer may have less than 2 anhydride groups per polymer molecule and may exhibit less than 10 % gel. (See also col 17, ln 14 -col 18, ln 11 of US Patent No. 5,429,758).

[0220] Alternately, in some embodiments, the acylated polymer may have a gel content of less than about 5 wt %, less than 3 wt %, less than 2 wt %, less than 1 wt %, less than 0.5 wt %, less than 0.1 wt %, or 0 wt %, where the gel content is measured by determining the amount of material that is extractable from the polymer by using boiling xylene (or cyclohexane) as an extractant. The percent of soluble and insoluble (gel) material in a polymer composition is

determined by soaking a nominally 0.5 mm thick thin film specimen of polymer for 48 hours in cyclohexane at 23° C or refluxing the thin film specimen in boiling xylene for one half hour, removing the solvent, weighing the dried residue and calculating the amount of soluble and insoluble (gel) material. This method is generally described in US Patent No. 4,311,628, which is incorporated herein by reference. For purposes of this disclosure, gel content is measured using boiling xylene, unless the sample is not soluble in xylene, then the cyclohexane method is used.

[0221] In embodiments, the acylated polymer may have a Saponification Number (SAP) of 5 g/KOH or more, such as 10 g/KOH or more, such as 20 g/KOH or more, such as 30 g/KOH or more, such as 50 g/KOH or more, such as 10 to 60 g/KOH, such as 20 to 40 g/KOH as determined by ASTM D94.

[0222] In embodiments, the acylated polymer composition may have less than 5 wt % unreacted acylating agent (such as maleic anhydride), such as less than 4 wt %, such as less than 3 wt %, such as less than 1 wt %, such as less than 0.5 wt %, such as less than 0.25 wt %, such as less than 0.1 wt %, based upon the weight of the acylated polymer composition (*i.e.*, polymer, acylating agent, and diluent).

[0223] In embodiments, the acylation reactions described herein may take place in base oil diluent. As a side product, functionalized base oil can be produced. The oil may become acylated itself. For example, maleated base oil may be present after the acylation reactions described herein.

[0224] It is contemplated that the functionalized base oil may comprise the acylated oil and/or the reaction product of the acylated oil with an amine to form an amide, imide or combination thereof.

[0225] Preferably, the acylated oil and/or reaction product of the acylated oil with an amine or alcohol to form an amide, imide, ester, or combination thereof, may be present in a concentrate in an amount of 40 wt % or less, alternately 20 wt % or less, alternately 10 wt % or less, alternately 5 wt % or less, alternately 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass % (such as 0 to 40 mass %, alternately 0.01 to 40 mass %, alternately 0.1 to 20 mass %, alternately to 1 to 10 mass %, alternately 1.5 to 5 mass %), based upon the weight of the concentrate composition.

[0226] Preferably one or more functionalized base oils, such as acylated oil and/or reaction product of the acylated oil with an amine or alcohol to form an amide, imide, ester, or combination thereof, may be present in the lubricating oil composition at an amount of 0.01 to 40 mass %, alternately 0.1 to 20 mass %, alternately to 1 to 10 mass %, alternately 1.5 to 5

mass %, (such as at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %), based upon the weight of the lubricating oil composition.

[0227] In embodiments, the acylation reactions described herein take place in solvent containing media. As a side product, acylated/functionalized solvent can be produced. In embodiments, acylated and/or functionalized solvent may be present in a concentrate composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the concentrate composition. In embodiments, functionalized solvent may be present in a lubricating oil composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the lubricating oil composition.

[0228] In embodiments, the acylating agent may be added in such a way as to minimize side reactions (such as reaction with base oil or other diluent present in the reaction vessel).

[0229] In embodiments, the acylating reaction may occur where the acylating agent (such as maleic acid or maleic anhydride) is added in a continuous or semi-continuous (such as intermittent) stream (such as, for example, in controlled relatively equal portions over the reaction time, or larger and/or smaller portions at different points in the reaction) to minimize functionalized base oil and other side reactions. As an example, the acylating agent may be added in a continuous fashion where the amounts of polymer and acylating agents are added in controlled stoichiometric amounts. As another example, the polymer may be added to a reaction vessel in batch fashion and the acylating agent added slowly or in a semi-continuous fashion (such as adding the acylating agent in 2 or more, such as 5 or more, such as 10 or more, such as 20 or more, such as 30 or more, such as 40 or more, such as 50 or more, such as 60 or more discrete amounts or portions). Alternately, the polymer can be added to the reaction vessel in X number of portions and the acylating agent added in 1.5X or more (such as 2X or more, such as 5X or more, such as 10X or more, such as 20X or more, such as 30X or more, such as 40X or more, such as 50X or more, such as 60X or more) number of portions. This same effect may also be achieved by diluting or concentrating a polymer solution and/or the acylating agent solution to the same or different extents.

[0230] Preferably, the acylating agent may be added in such a way as to minimize side reactions, such as in a continuous or semi-continuous fashion.

[0231] The reaction may also be run so as to minimize side reactions by using high concentrations of the polymer in diluent, such as 45 wt % or more, or 50 wt % or more, or 55

wt % or more, or 60 wt % or more in batch, semi-continuous, or continuous reactor operations. For example, the polymer (such as a hydrogenated isoprene polymer, such as hydrogenated homo-polyisoprene) may be introduced into batch, semi-continuous, or continuous reactor operations as solution or suspension (such as a slurry) in diluent (such as oil (e.g., base oil, such as a Group I, II, III, IV, and/or V base oil, such as a Group II and/or Group III base oil) or alkane solvent or diluent or a combination thereof), where the polymer may be present in the solution or suspension at 45 wt % or more (or 50 wt % or more, or 55 wt % or more, or 60 wt % or more), based upon the weight of the polymer and diluent.

[0232] In embodiments, the side reactions may be minimized by: 1) adding the acylating agent in a continuous or semi-continuous fashion, and/or 2) the polymer is introduced into batch, semi-continuous or continuous reactor operations as solution or suspension in diluent where the polymer is present at 45 wt % or more, based upon the weight of the polymer and diluent.

[0233] In embodiments, side reactions are minimized, optionally by adding the acylating agent in a continuous or semi-continuous fashion, and/or by introducing the fully or partially hydrogenated polymer (such as isoprene polymer) into batch, semi-continuous, or continuous reactor operations as solution or suspension in diluent, said solution or suspension comprising 45 wt % or more (or 50 wt % or more, or 55 wt % or more, or 60 wt % or more), of the fully or partially hydrogenated polymer, based upon the weight of the fully or partially hydrogenated polymer and diluent.

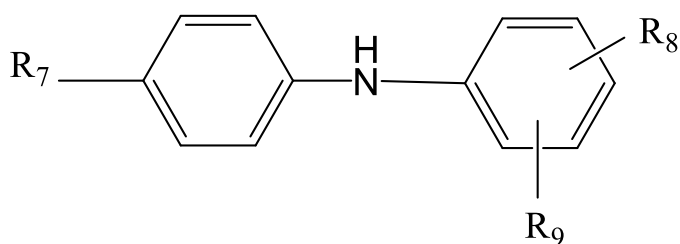
[0234] In embodiments, side reactions are minimized, optionally by adding the acylating agent in a continuous or semi-continuous fashion, and by introducing the fully or partially hydrogenated polymer (such as isoprene polymer) into batch, semi-continuous, or continuous reactor operations as solution or suspension in diluent, said solution or suspension comprising 45 wt % or more (or 50 wt % or more, or 55 wt % or more, or 60 wt % or more), of the fully or partially hydrogenated polymer, based upon the weight of the fully or partially hydrogenated polymer and diluent.

Functionalization

[0235] In embodiments, the acylated polymer may be reacted with an alcohol or an amine to form an amide, imide, ester or combinations thereof. The reaction may consist of condensation to form an imide, an amide, a half-amide, amide-ester, diester, or an amine salt. A primary amino group will typically condense to form an amide or, in the case of maleic anhydride, an imide. It is noted the amine may have a single primary amino group or multiple primary amino groups.

[0236] Suitable amines may include one or more aromatic amines, such as amines wherein a carbon atom of the aromatic ring structure is attached directly to the amino nitrogen. The amine may also be aliphatic. In embodiments aliphatic amines can be used alone or in combination with each other or in combination with aromatic amines. The amount of aromatic amine may, in some embodiments, be a major or minor amount compared with the amount of the non-aromatic amines, or in some instances, the composition may be substantially free of aromatic amine. Alternately, the composition may be substantially free of aliphatic amine.

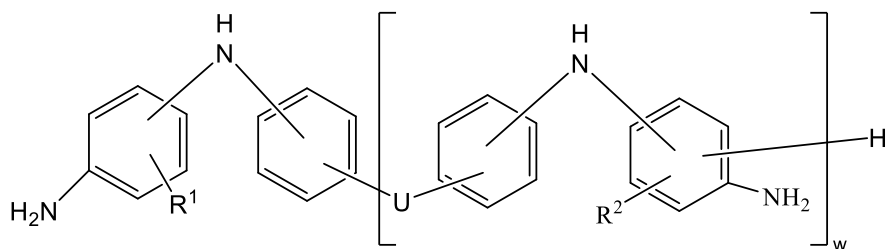
[0237] Examples of aromatic amines which may be used herein include one or more N-arylphenylenediamine(s) represented by the formula:



wherein R_7 is H, $-\text{NHaryl}$, $-\text{NHalkaryl}$, or a branched or straight chain hydrocarbyl radical having from about 4 to about 24 carbon atoms selected from alkyl, alkenyl, alkoxy, aralkyl or alkaryl; R_9 is $-\text{NH}_2$, $-(\text{NH}(\text{CH}_2)_n)_m\text{NH}_2$, $-\text{NHalkyl}$, $-\text{NHaralkyl}$, $-\text{CH}_2\text{-aryl-NH}_2$, in which n and m each have a value from about 1 to about 10; and R_8 is hydrogen, or alkyl, alkenyl, alkoxy, aralkyl, or alkaryl, having from about 4 to about 24 carbon atoms.

[0238] Suitable N-arylphenylenediamines include N-phenylphenylenediamines (NPPDA), for example, N-phenyl-4,4'-phenylenediamine, N-phenyl-1,3-phenylenediamine, and N-phenyl-1,2-phenylenediamine and N-naphthyl-1,4-phenylenediamine. Other derivatives of NPPDA may also be included, such as N-propyl-N'-phenylphenylenediamine.

[0239] In embodiments, the amine reacted with the acylated polymer is an amine having at least 3 or 4 aromatic groups and may be represented by the following formula:

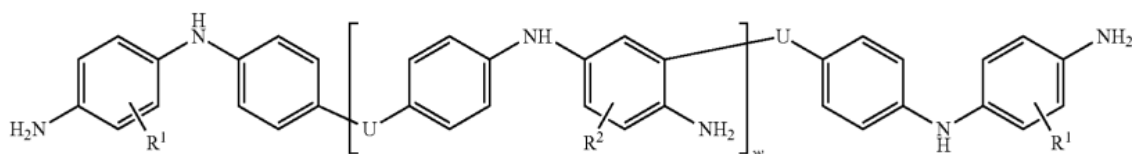


wherein independently each variable, R^1 may be hydrogen or a C_1 to C_5 alkyl group (typically hydrogen); R^2 may be hydrogen or a C_1 to C_5 alkyl group (typically hydrogen); U may be an aliphatic, alicyclic or aromatic group, with the proviso that when U is aliphatic, the aliphatic

[0240] Other examples of aromatic amines include aniline, N-alkylanilines such as N-methyl aniline, and N-butylaniline, di-(para-methylphenyl)amine, naphthylamine, 4-aminodiphenylamine, N,N-dimethylphenylenediamine, 4-(4-nitro-phenylazo)aniline (disperse orange 3), sulfamethazine, 4-phenoxyaniline, 3-nitroaniline, 4-aminoacetanilide, 4-amino-2-hydroxy-benzoic acid phenyl ester (phenyl amino salicylate), N-(4-amino-5-methoxy-2-methyl-phenyl)-benzamide (fast violet B), N-(4-amino-2,5-dimethoxy-phenyl)-benzamide (fast blue RR), N-(4-amino-2,5-diethoxy-phenyl)-benzamide (fast blue BB), N-(4-amino-phenyl)-benzamide and 4-phenylazoaniline. Suitable amines are referenced in US Patent No. 7,790,661 and are hereby incorporated by reference.

$$\begin{array}{c} \text{H} \\ \diagdown \\ \text{N} - \text{X} - \text{N} \\ \diagup \quad \diagdown \\ \text{R}^2 \quad \text{R}^3 \\ \quad \quad \quad \diagup \\ \quad \quad \quad \text{R}^4 \end{array}$$
$$\text{HO}-\text{X}-\text{N} \begin{array}{l} \nearrow \text{R}^3 \\ \searrow \text{R}^4 \end{array}$$

[0242] Alternately, the amine may be an amine having at least 4 aromatic groups and an aldehyde (such as formaldehyde). The aromatic amine may be represented by formula:



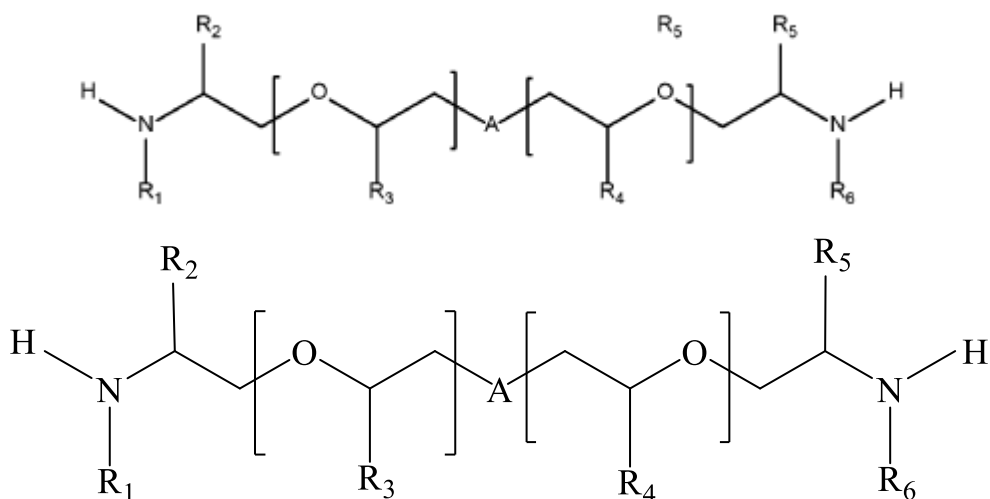
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the proviso that when U is aliphatic, the aliphatic group may be linear or branched alkylene group containing 1, 2, 3, 4, or 5, or 1 to 2 carbon atoms; and w is 0, 1, 2, 3, 4, 5, 6, 7, 8, or 9, such as 0, 1, 2, or 3 or 0 or 1 (typically 0). For further information on such amines see, *e.g.*, US 2017/0073606, page 5 paragraph [0064]-[0070] and European Patent No. 2 401 348.

[0243] Examples of compounds capable of condensing with the acylating agent and further having a tertiary amino group can include but are not limited to: dimethylaminopropylamine, N,N-dimethyl-aminopropylamine, N,N-diethyl-aminopropylamine, N,N-dimethyl-aminoethylamine ethylenediamine, 1,2-propylenediamine, 1,3-propylenediamine, the isomeric butylenediamines, pentanediamines, hexanediamines, heptanediamines, diethylenetriamine, dipropylenetriamine, dibutylenetriamine, triethylenetetraamine, tetraethylene pentaamine, pentaethylenhexaamine, hexamethylenetetramine, and bis (hexamethylene) triamine, the diaminobenzenes, the diaminopyridines or mixtures thereof. The compounds capable of condensing with the acylating agent and further having a tertiary amino group can further include aminoalkyl substituted heterocyclic compounds such as 1-(3-aminopropyl)imidazole and 4-(3-aminopropyl)morpholine, 1-(2-aminoethyl)piperidine, 3,3-di-amino-N-methyldipropylamine, 3',3'-aminobis(N,N-dimethylpropylamine). Another example of compounds capable of condensing with the acylating agent and having a tertiary amino group include alkanolamines including, but not limited to, triethanolamine, trimethanolamine, N,N-dimethylaminopropanol, N,N-di-ethylaminopropanol, N,N-diethylaminobutanol, N,N,N-tris(hydroxyethyl)amine, N,N,N-tris(hydroxymethyl)amine.

[0244] In embodiments, the polymer may be reacted with a polyether aromatic compound. Typically, the polyether aromatic compound will have at least two functional groups, each capable of reacting with a monocarboxylic acid or ester thereof, or dicarboxylic acid, anhydride or ester thereof, or mixtures thereof. In embodiments, the polyether aromatic compound is derived from an aromatic compound containing at least one amine group and wherein the poly ether is capable of reacting with a monocarboxylic acid or ester thereof, or dicarboxylic acid, anhydride or ester thereof.

[0245] Examples of suitable polyether aromatic amines include compounds having the following structure:



in which A represents an aromatic aminic moiety wherein the ether groups are linked through at least one amine group on the aromatic moiety; R₁ and R₆ are independently hydrogen, alkyl, alkaryl, aralkyl, or aryl or mixtures thereof; R₂, R₃, R₄, and R₅ are independently hydrogen or alkyl containing from about 1 to about 6 carbon atoms of mixtures thereof; and a and x are independently integers from about 1 to about 50.

[0246] The acylated polymer may be reacted with a polyether amine or polyether polyamine. Typical polyether amine compounds contain at least one ether unit and are chain terminated with at least one amine moiety. The polyether polyamines can be based on polymers derived from C₂-C₆ epoxides such as ethylene oxide, propylene oxide, and butylene oxide. Examples of polyether polyamines are sold under the Jeffamine™ brand and are commercially available from Hunstman Corporation.

[0247] Amines useful herein for combination with the acylated polymer include one or more of: N-phenyldiamines (such as N-phenyl-1,4-phenylenediamine, N-phenyl-p-phenylenediamine (a.k.a. 4-amino-diphenylamine, ADPA), N-phenyl-1,3-phenylenediamine, N-phenyl-1,2-phenylenediamine), nitroaniline (such as 3-nitroaniline), N-phenylethane-diamine (such as N1-phenylethane-1,2-diamine), N-aminophenylacetamide (such as N-(4-aminophenyl)acetamide), morpholinopropanamine (such as 3-morpholinopropan-1-amine), and aminoethylpiperazine (such as 1-(2-aminoethyl)piperazine).

[0248] In embodiments, the functionalization (such as amination) reactions described herein may take place in diluent (such as base oil or alkane solvent). As a side product, functionalized diluent (such as functionalized base oil) can be produced. It is contemplated that the functionalized diluent (such as functionalized base oil) may comprise reaction product of the acylated diluent (such as acylated base oil) with an amine to form an amide, imide or combination thereof.

[0249] Preferably, the reaction product of the acylated diluent (such as acylated oil) with an amine or alcohol to form an amide, imide, ester, or combination thereof, may be present in a concentrate in an amount of 40 wt % or less, alternately 20 wt % or less, alternately 10 wt % or less, alternately 5 wt % or less, alternately 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass % (such as 0 to 40 mass %, alternately 0.01 to 40 mass %, alternately 0.1 to 20 mass %, alternately to 1 to 10 mass %, alternately 1.5 to 5 mass %), based upon the weight of the concentrate composition.

[0250] Preferably one or more functionalized base oils, such as the reaction product of the acylated diluent (such as acylated base oil) with an amine or alcohol to form an amide, imide, ester, or combination thereof, may be present in the lubricating oil composition at an amount of 0.01 to 40 mass %, alternately 0.1 to 20 mass %, alternately to 1 to 10 mass %, alternately 1.5 to 5 mass %, (such as at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %), based upon the weight of the lubricating oil composition.

[0251] In embodiments, the functionalization (such as amination) reactions described herein may take place in solvent-containing media. As a side product, functionalized solvent can be produced. In embodiments, the functionalized solvent may be present in a concentrate composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the concentrate composition. In embodiments, functionalized solvent may be present in a lubricating oil composition at 3 mass % or less, preferably 2 mass % or less, preferably 1 mass % or less, preferably at 0.1 mass % or less, preferably at 0 mass %, based upon the weight of the lubricating oil composition.

[0252] In embodiments, the acylated base oil/solvent may be removed prior to functionalization.

Functionalized Polymer

[0253] The functionalized polymer may be a homopolymer of C₄ or C₅ olefins, such as butadiene and isoprene.

[0254] In embodiments, the functionalized polymer may be a homopolymer of isoprene, or a copolymer of isoprene and less than 5 mol % (such as less than 3 mol %, such as less than 1 mol %, such as less than 0.1 mol %) comonomer.

[0255] The functionalized polymer may comprise or be a copolymer of isoprene and one or more of styrene, methyl-styrene, 2,3-dimethyl-butadiene, 2-methyl-1,3-pentadiene, myrcene, 3-methyl-1,3-pentadiene, 4-methyl-1,3-pentadiene, 2-phenyl-1,3-butadiene, 2-phenyl-1,3-

pentadiene, 3-phenyl-1,3 pentadiene, 2,3-dimethyl-1,3-pentadiene, 2-hexyl-1,3-butadiene, 3-methyl-1,3-hexadiene, 2-benzyl-1,3-butadiene, 2-p-tolyl-1,3-butadiene 1,3-butadiene, 1,3-pentadiene, 1,3-hexadiene, 1,3-heptadiene, 2,4-heptadiene, 1,3-octadiene, 2,4-octadiene, 3,5-octadiene, 1,3-nonadiene, 2,4-nonadiene, 3,5-nonadiene, 1,3-decadiene, 2,4-decadiene, and 3,5-decadiene, (optionally the comonomer(s) are present at less than 20 mol %, less than 5 mol %, such as less than 3 mol %, such as less than 1 mol %, such as less than 0.1 mol %)

[0256] In embodiments, the functionalized polymer comprises 10 (such as 9, such as 8, such as 7, such as 6, such as 5, such as 4, such as 3, such as 2, such as 1) wt %, or less, based upon the weight of the functionalized polymer, of styrene monomer.

[0257] In embodiments, styrene repeat units may be absent in the functionalized polymer.

[0258] In embodiments, the functionalized polymer may be a block or tapered block copolymer that does not comprise a styrene block.

[0259] In embodiments, the functionalized polymer may be a block or tapered block copolymer comprising (or consisting of or consisting essentially of) isoprene.

[0260] In embodiments, the functionalized polymer may be a block or tapered block copolymer comprising 50 wt % or more isoprene, based upon the weight of the copolymer.

[0261] In embodiments, the functionalized polymer may be a block or tapered block copolymer comprising (or consisting of or consisting essentially of) C₄₋₅ conjugated diene, preferably comprising 50 (such as 60, such as 70, such as 80, such as 90, such as 95, such as 98) wt % or more C₄₋₅ conjugated diene, based upon the weight of the copolymer.

[0262] In embodiments, the functionalized polymer may be a copolymer comprising 50 (such as 60, such as 70, such as 80, such as 90, such as 95, such as 98) wt % or more isoprene, based upon the weight of the copolymer.

[0263] In embodiments, the functionalized polymer may be a copolymer comprising 50 (such as 60, such as 70, such as 80, such as 90, such as 95, such as 98) wt % or more butadiene, based upon the weight of the copolymer.

[0264] In embodiments, the functionalized polymer may be a copolymer comprising 50 (such as 60, such as 70, such as 80, such as 90, such as 95, such as 98) wt % or more butadiene and isoprene, based upon the weight of the copolymer.

[0265] In embodiments, the functionalized polymer may be a di-block copolymer comprising at least one block of isoprene homo-or co- polymer.

[0266] Optionally, butadiene repeat units may be absent in the functionalized polymer.

[0267] Optionally, the functionalized polymer may be not homopolyisobutylene.

[0268] Optionally, the functionalized polymer may be not a copolymer of isoprene and butadiene.

[0269] Generally, the polymerized conjugated diene in the functionalized polymer includes monomer units that have been inserted in the growing polymer chain by conjugated addition and non-conjugated addition. In embodiments the functionalized polymer contains at least about 50 % of by conjugated addition insertions, such as at least about 75 % of by conjugated addition insertions, such as about 80 % of by conjugated addition insertions, such as from about 85 % to about 100 % of by conjugated addition insertions, based upon the total number of by conjugated addition and non-conjugated insertions, as measured by ^{13}C NMR.

[0270] The insertion of isoprene most often occurs by 2,1 insertions, 1,4 insertions (trans and cis), and 3,4 insertions of isoprene. (Measurements of the insertion geometry are determined by ^1H NMR.) As measured by ^1H NMR, the functionalized isoprene polymer contains at least about 50 % of 1,4-insertions, such as at least about 75 % of 1,4 insertions, such as at least about 80 % of 1,4 insertions, such as at least about 90 % of 1,4 insertions, such as at least about 95 % of 1,4 insertions, such as at least 98 % of 1,4 insertions, based upon the total of the 2,1 insertions, 1,4 insertions, and 3,4 insertions of isoprene. For purposes of this disclosure: 1) the phrase "1,4 insertion" includes 1,4 and 4,1 insertions, 2) the phrase "2,1 insertion" includes 2,1 and 1,2 insertions, and 3) the phrase "3,4 insertion" includes 3,4 and 4,3 insertions.

[0271] The functionalized polymer may be homopolymer or copolymer. Optionally, the functionalized polymer comprises a homopolymer or copolymer of isoprene. The copolymer may be a random copolymer, a tapered block copolymer, a star copolymer, or a block copolymer.

[0272] The functionalized polymer may typically have an M_n of 20,000 to 150,000 g/mol, alternately 20,000 to about 150,000 g/mol, alternately 30,000 to about 125,000 g/mol, alternately 35,000 to about 100,000 g/mol, alternately 40,000 to 80,000 g/mol (GPC-PS).

[0273] The polymer prior to functionalization may typically have an M_n/M_w (GPC-PS) of 1.0 to 2, such as 1.1 to 1.5, such as 1.1 to 1.3, such as 1.1 to 1.2. As functionalization occurs, M_w/M_n broadening may occur.

[0274] The functionalized polymer may typically have an M_w/M_n (GPC-PS) of 1 to 3, alternately 1 to 2, alternately greater than 1 to less than 2, alternately 1.05 to 1.9, alternately 1.10 to 1.8, alternately 1.10 to 1.7, alternately 1.12 to 1.6, alternately 1.13 to 1.5, alternately 1.15 to 1.4, alternately 1.15 to 1.3. Alternately, the functionalized polymer may typically have an M_w/M_n of 1 or greater than 1 to less than 2 (such as less than 1.8, such as less than 1.7, such

as less than 1.6, such as less than 1.4, such as less than 1.2, such as less than 1.15, such as less than 1.12, such as less than 1.10).

[0275] In embodiments, the functionalized polymer may have a Saponification Number (SAP) of 25 (such as 28, such as 30, such as 32, such as 34) mgKOH/g or more, as determined by ASTM D94.

[0276] In embodiments, the functionalized polymer may contribute 17% or more (such as 20 % or more, such as 17 to 40 %, such as 20 to 30 %) to the Saponification Number of the lubricating oil composition.

[0277] In embodiments, the functionalized polymer may have an average functionality of 1.4 to 20 FG grafts/polymer chain, such as 1.4 to 15 FG grafts/polymer chain, such as 3 to 12.5 FG grafts/polymer chain, such as 4 to 10 FG grafts/polymer chain, as determined by GPC-PS.

[0278] The functionalized polymer may have an average functionality of 15 (such as 14, 13, 12, 11, 10, 9, 8, 7, or 6) or less FG grafts/polymer chain, as determined by GPC-PS.

[0279] The functionalized polymer may have an average functionality of 1 (such as 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, or 4.0) or more FG grafts/polymer chain, as determined by GPC-PS.

[0280] The functionalized polymer may have an average functionality from 1 (such as 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, or 4.0) to 15 (such as 14, 13, 12, 11, 10, 9, 8, 7, or 6) FG grafts/polymer chain, as determined by GPC-PS.

[0281] In embodiments, the functionalized polymer may have an aromatic content of 5 % or less, such as 3 % or less, such as 1 % or less, such as 0 %, based upon the weight of the polymer.

[0282] In embodiments, the functionalized polymer may comprise acylated polymers of branched C₄₋₅ monomers having an Mn of 20,000 to 500,000 g/mol having an Mw/Mn of 2 or less, such as from 1 to 2.0, as determined by GPC-PS.

[0283] In embodiments, the functionalized polymer may have a number average molecular weight (Mn) of 20,000 (such as 25,000, such as 30,000, such as 35,000 such as 40,000) g/mol or more, as determined by GPC-PS.

[0284] In embodiments, the functionalized polymer may have a weight average molecular weight (Mw) of 50,000 (such as 40,000, such as 35,000) g/mol or less, as determined by GPC-PS. In embodiments, the functionalized polymer may have a weight average molecular weight (Mw) of 1000 to 50,000 g/mol, such as 5000 to 40,000 g/mol as determined by GPC-PS.

[0285] In embodiments, the functionalized polymer may have a z average molecular weight (Mz) of 5000 to 150,000 g/mol, such as 10,000 to 150,000 g/mol, such as 15,000 to 70,000 g/mol, such as 20,000 to 150,000 g/mol, alternately 20,000 to about 150,000 g/mol, alternately 30,000 to about 125,000 g/mol, alternately 35,000 to about 100,000 g/mol, alternately 40,000 to 80,000 g/mol, alternately 40,000 to 60,000 g/mol (GPC-PS).

[0286] In embodiments, the functionalized polymer may have a gel content of less than about 5 wt %, less than 3 wt %, less than 2 wt %, less than 1 wt %, less than 0.5 wt %, less than 0.1 wt %, or 0 wt %, where the gel content is measured by determining the amount of material that is extractable from the polymer by using boiling xylene (or cyclohexane) as an extractant. The percent of soluble and insoluble (gel) material in a polymer composition is determined as described herein.

[0287] In embodiments, the functionalized polymer may have a Functionality Distribution (Fd) value of 3.5 or less (such as 3.4 or less, such as from 1 to 3.3, such as from 1.1 to 3.2, such as from 1.2 to 3.0, such as 1.4 to 2.9, as determined by GPC-PS). Functionality Distribution (Fd) value is determined as set out in the Example section below and an average functionality of 1.4 to 20 FG grafts/polymer chain, such as 1.4 to 15 FG grafts/polymer chain, such as 3 to 12.5 FG grafts/polymer chain, such as 4 to 10 FG grafts/polymer chain, as determined by GPC-PS.

[0288] This disclosure relates to amide, imide, and/or ester functionalized hydrogenated/saturated polymers comprising (consisting essentially of or consisting of) C₄₋₅ olefins having an Mw/Mn of less than 2, a Functionality Distribution (Fd) value of 3.5 or less (such as 3.4 or less, such as from 1 to 3.3, such as from 1.1 to 3.2, such as from 1.2 to 3.0, such as 1.4 to 2.9, as determined by GPC-PS), and wherein, if the polymer prior to functionalization is a C₄ olefin polymer such as polyisobutylene, polybutadiene, or a copolymer thereof (preferably a polyisobutylene or a copolymer of isobutylene and butadiene), then the C₄ olefin polymer has an Mn of 10,000 g/mol or more (GPC-PS), and if the polymer prior to functionalization is a C₄/C₅ copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 Mn (GPC-PS).

[0289] This disclosure also relates to amide, imide, and/or ester functionalized hydrogenated/saturated polymers comprising 90 mol % or more isoprene repeat units, having an Mw/Mn of less than 2, a Functionality Distribution (Fd) value of 3.5 or less (such as 3.4 or less, such as from 1 to 3.3, such as from 1.1 to 3.2, such as from 1.2 to 3.0, such as 1.4 to 2.9, as determined by GPC-PS), and wherein the polymer prior to functionalization has an Mn of 30,000 g/mol or more (GPC-PS).

[0290] This disclosure also relates to amide, imide, and/or ester functionalized hydrogenated/saturated homopolymers of isoprene having an Mw/Mn of less than 2, a Functionality Distribution (Fd) value of 3.5 or less (such as 3.4 or less, such as from 1 to 3.3, such as from 1.1 to 3.2, such as from 1.2 to 3.0, such as 1.4 to 2.9, as determined by GPC-PS), and wherein the polymer prior to functionalization has an Mn of 30,000 g/mol or more (as determined by GPC-PS).

[0291] The lubricating composition according to the present disclosure may further comprise one or more additives such as detergents, friction modifiers, antioxidants, pour point depressants, anti-foam agents, viscosity modifiers, dispersants, corrosion inhibitors, antiwear agents, extreme pressure additives, demulsifiers, seal compatibility agents, additive diluent base oils, etc. Specific examples of such additives are described in, for example, Kirk-Othmer Encyclopedia of Chemical Technology, third edition, volume 14, pp. 477-526, and several are discussed in further detail below.

C. Detergents

[0292] The lubricating composition may comprise one or more metal detergents (such as blends of metal detergents) also referred to as a "detergent additive." Metal detergents typically function both as detergents to reduce or remove deposits and as acid neutralizers or rust inhibitors, thereby reducing wear and corrosion and extending engine life. Detergents generally comprise a polar head with a long hydrophobic tail, with the polar head comprising a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal in which case they are usually described as normal or neutral salts, and would typically have a total base number ("TBN" as measured by ASTM D2896) of up to 150 mgKOH/g, such as from 0 to 80 (or 5-30) mgKOH/g. A large amount of a metal base may be incorporated by reacting excess metal compound (*e.g.*, an oxide or hydroxide) with an acidic gas (*e.g.*, carbon dioxide). Such detergents, sometimes referred to as overbased, may have a TBN of 100 mgKOH/g or more (such as 200 mgKOH/g or more), and typically will have a TBN of 250 mgKOH/g or more, such as 300 mgKOH/g or more, such as from 200 to 800 mgKOH/g, 225 to 700 mgKOH/g, 250 to 650 mgKOH/g, or 300 to 600 mgKOH/g, such as 150 to 650 mgKOH/g.

[0293] Suitable detergents include, oil-soluble neutral and overbased sulfonates, phenates, sulfurized phenates, thiophosphonates, salicylates, naphthenates and other oil-soluble carboxylates of a metal, particularly the alkali metals (Group 1 metals, *e.g.*, Li, Na, K, Rb) or alkaline earth metals (Group 2 metals, *e.g.*, Be, Mg, Ca, Sr, Ba), particularly, sodium, potassium, lithium, calcium, and magnesium, such as Ca and/or Mg. Furthermore, the

detergent may comprise a hybrid detergent comprising any combination of sodium, potassium, lithium, calcium, or magnesium salts of sulfonates, phenates, sulfurized phenates, thiophosphonates, salicylates, and naphthenates or other oil-soluble carboxylates of a Group 1 and/or 2 metal.

[0294] Preferably, the detergent additive(s) useful in the present disclosure comprises calcium and/or magnesium metal salts. The detergent may be a calcium and/or magnesium carboxylate (*e.g.*, salicylates), sulfonate, or phenate detergent. More preferably, the detergent additives are selected from magnesium salicylate, calcium salicylate, magnesium sulfonate, calcium sulfonate, magnesium phenate, calcium phenate, and hybrid detergents comprising two, three, four, or more of more of these detergents and/or combinations thereof.

[0295] The metal-containing detergent may also include "hybrid" detergents formed with mixed surfactant systems including phenate and/or sulfonate components, *e.g.*, phenate/salicylates, sulfonate/phenates, sulfonate/salicylates, sulfonates/phenates/salicylates, as described, for example, in US Patent Nos. 6,429,178; 6,429,179; 6,153,565; and 6,281,179. Where, for example, a hybrid sulfonate/phenate detergent is employed, the hybrid detergent would be considered equivalent to amounts of distinct phenate and sulfonate detergents introducing like amounts of phenate and sulfonate soaps, respectively.

[0296] The overbased metal-containing detergent may be sodium salts, calcium salts, magnesium salts, or mixtures thereof of the phenates, sulfur-containing phenates, sulfonates, salixarates, and salicylates. Overbased phenates and salicylates typically have a total base number of 180 to 650 mgKOH/g, such as 200 to 450 TBN mgKOH/g. Overbased sulfonates typically have a total base number of 250 to 600 mgKOH/g, or 300 to 500 mgKOH/g. In embodiments, the sulfonate detergent may be predominantly a linear alkylbenzene sulfonate detergent having a metal ratio of at least 8 as is described in paragraphs [0026] to [0037] of US Patent Application Publication No. 2005/065045 (and granted as US Patent No. 7,407,919). The overbased detergent may be present at 0 wt % to 15 wt %, or 0.1 wt % to 10 wt %, or 0.2 wt % to 8 wt %, or 0.2 wt % to 3 wt %, based upon of the lubricating composition. For example, in a heavy-duty diesel engine, the detergent may be present at 2 wt % to 3 wt % of the lubricating composition. For a passenger car engine, the detergent may be present at 0.2 wt % to 1 wt % of the lubricating composition.

[0297] The detergent additive(s) may comprise one or more magnesium sulfonate detergents. The magnesium detergent may be a neutral salt or an overbased salt. Suitably the magnesium detergent is an overbased magnesium sulfonate having a TBN of from 80 to 650 mgKOH/g (ASTM D2896), such as 200 to 500 mgKOH/g, such as 240 to 450 mgKOH/g.

[0298] Alternately, the detergent additive(s) is a magnesium salicylate. Suitably the magnesium detergent is a magnesium salicylate having TBN of from 30 to 650 mgKOH/g (ASTM D2896), such as 50 to 500 mgKOH/g, such as 200 to 500 mgKOH/g, such as 240 to 450 mgKOH/g or alternately of 150 mgKOH/g or less, such as 100 mgKOH/g or less.

[0299] Alternately, the detergent additive(s) is a combination of magnesium salicylate and magnesium sulfonate.

[0300] The magnesium detergent provides the lubricating composition thereof with from 200-4000 ppm of magnesium atoms, suitably from 200-2000 ppm, from 300 to 1500 or from 450-1200 ppm of magnesium atoms (ASTM D5185).

[0301] The detergent composition may comprise (or consist of) a combination of one or more magnesium sulfonate detergents and one or more calcium salicylate detergents.

[0302] The combination of one or more magnesium sulfonate detergents and one or more calcium salicylate detergents provides the lubricating composition thereof with: 1) from 200-4000 ppm of magnesium atoms, suitably from 200-2000 ppm, from 300 to 1500 ppm or from 450-1200 ppm of magnesium atoms (ASTM D5185), and 2) at least 500 ppm, preferably at least 750 ppm, more preferably at least 900 ppm of atomic calcium, such as from 500-4000 ppm, preferably from 750-3000 ppm, more preferably from 900-2000 ppm atomic calcium (ASTM D5185).

[0303] The detergent may comprise one or more calcium detergents such as calcium carboxylate (*e.g.*, salicylate), sulfonate, or phenate detergent.

[0304] Suitably the calcium detergent has a TBN of from 30 to 700 mgKOH/g (ASTM D2896), such as 50 to 650 mgKOH/g, such as 200 to 500 mgKOH/g, such as 240 to 450 mgKOH/g or alternately of 150 mgKOH/g or less, such as 100 mgKOH/g or less, or 200 mgKOH/g or more, or 300 mgKOH/g or more, or 350 mgKOH/g or more.

[0305] Suitably, the calcium detergent is a calcium salicylate, sulfonate, or phenate having a TBN of from 30 to 700 mgKOH/g, 30 to 650 mgKOH/g (ASTM D2896), such as 50 to 650 mgKOH/g, such as 200 to 500 mgKOH/g, such as 240 to 450 mgKOH/g or alternately of 150 mgKOH/g or less, such as 100 mgKOH/g or less, or 200 mgKOH/g or more, or 300 mgKOH/g or more, or 350 mgKOH/g or more.

[0306] Calcium detergent is typically present in amount sufficient to provide at least 500 ppm, preferably at least 750 more preferably at least 900 ppm atomic calcium to the lubricating oil composition (ASTM D5185). If present, any calcium detergent is suitably present in amount sufficient to provide no more than 4000 ppm, preferably no more than 3000 ppm, more preferably no more than 2000 ppm atomic calcium to the lubricating oil composition (ASTM

D5185). If present, any calcium detergent is suitably present in amount sufficient to provide at from 500-4000 ppm, preferably from 750-3000 ppm more preferably from 900-2000 ppm atomic calcium to the lubricating oil composition (ASTM D5185).

[0307] Suitably the total atomic amount of metal from detergent in the lubrication composition according to all aspects of the disclosure is no more than 5000 ppm, preferably no more than 4000 pm and more preferably no more than 2000 ppm (ASTM D5185). The total amount of atomic metal from detergent in the lubrication oil composition according to all aspects of the disclosure is suitably at least 500 ppm, preferably at least 800 ppm and more preferably at least 1000 ppm (ASTM D5185). The total amount of atomic metal from detergent in the lubrication oil composition according to all aspects of the disclosure is suitably from 500 to 5000 ppm, preferably from 500 to 3000 ppm and more preferably from 500 to 2000 ppm (ASTM D5185).

[0308] Sulfonate detergents 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 includ those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl, or their halogen derivatives such as chlorobenzene, chlorotoluene, and chloronaphthalene. 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 about 80 or more carbon atoms, preferably from about 16 to about 60 carbon atoms per alkyl substituted aromatic moiety. The oil soluble sulfonates or alkaryl sulfonic acids may be neutralized with oxides, hydroxides, alkoxides, carbonates, carboxylate, sulfides, hydrosulfides, nitrates, borates and ethers of the metal. The amount of metal compound is chosen having regard to the desired TBN of the final product, but typically ranges from about 100 to 220 mass % (preferably at least 125 mass %) of that stoichiometrically required.

[0309] Metal salts of phenols and sulfurized phenols are prepared by reaction with an appropriate metal compound such as an oxide or hydroxide and neutral or overbased products may be obtained by methods well known in the art. Sulfurized phenols may be prepared by reacting a phenol with sulfur or a sulfur-containing compound such as hydrogen sulfide, sulfur monohalide, or sulfur dihalide, to form products which are generally mixtures of compounds in which 2 or more phenols are bridged by sulfur-containing bridges.

[0310] Carboxylate detergents, *e.g.*, salicylates, can be prepared by reacting an aromatic carboxylic acid (such as a C₅₋₁₀₀, C₉₋₃₀, C₁₄₋₂₄ alkyl-substituted hydroxy-benzoic acid) with an appropriate metal compound such as an oxide or hydroxide and neutral or overbased products

may be obtained by methods well known in the art. The aromatic moiety of the aromatic carboxylic acid can contain heteroatoms, such as nitrogen and oxygen. Preferably, the moiety contains only carbon atoms; more preferably the moiety contains six or more carbon atoms; for example, benzene is a preferred moiety. The aromatic carboxylic acid may contain one or more aromatic moieties, such as one or more benzene rings, either fused or connected via alkylene bridges.

[0311] Preferred substituents in oil-soluble salicylic acids are alkyl substituents. In alkyl-substituted salicylic acids, the alkyl groups advantageously contain 5 to 100, preferably 9 to 30, especially 14 to 20, carbon atoms. Where there is more than one alkyl group, the average number of carbon atoms in all of the alkyl groups is preferably at least 9 to ensure adequate oil solubility.

[0312] In embodiments, the ratio of atomic detergent metal to atomic molybdenum in the lubricating oil composition may be less than 3:1, such as less than 2:1.

[0313] Further, as metal organic and inorganic base salts, which are used as detergents can contribute to the sulfated ash content of a lubricating oil composition, in embodiments of the present disclosure, the amounts of such additives are minimized. In order to maintain a low sulfur level, salicylate detergents can be used and the lubricating composition herein may comprise one or more salicylate detergents (said detergents are preferably used in amounts in the range of 0.05 to 20.0 wt %, more preferably from 1.0 to 10.0 wt % and most preferably in the range of from 2.0 to 5.0 wt %, based on the total weight of the lubricating composition).

[0314] The total sulfated ash content of the lubricating composition herein is typically not greater than 2.0 wt %, alternately at a level of not greater than 1.0 wt % and alternately at a level of not greater than 0.8 wt %, based on the total weight of the lubricating composition as determined by ASTM D874.

[0315] Furthermore, it is useful that each of the detergents, independently, have a TBN (total base number) value in the range of from 10 to 700 mgKOH/g, 10 to 500 mgKOH/g, alternately in the range of from 100 to 650, alternately in the range of from 10 to 500 mgKOH/g, alternately in the range of from 30 to 350 mgKOH/g, and alternately in the range of from 50 to 300 mgKOH/g, as measured by ISO 3771.

[0316] The sulfonate detergents (such as Ca and/or Mg sulfonate detergents) may be present in an amount to deliver 0.1 wt % to 1.5 wt %, or 0.15 to 1.2 wt %, or 0.2 wt % to 0.9 wt % sulfonate soap to the lubricant composition.

[0317] The salicylate detergents (such as Ca and/or Mg salicylate detergents) are present in an amount to deliver 0.3 wt % to 1.4 wt %, or 0.35 wt % to 1.2 wt %, or 0.4 wt % to 1.0 wt % salicylate soap to the lubricant composition.

[0318] The sulfonate soap may be present in an amount 0.2 wt % to 0.8 wt % of the lubricant composition, and the salicylate soap may be present in an amount 0.3 wt % to 1.0 wt % of the lubricant composition.

[0319] The total of all alkaline earth metal detergent soap may be present in an amount 0.6 wt % to 2.1 wt %, or 0.7 wt % to 1.4 wt % of the lubricant composition.

[0320] Typically, lubricating compositions formulated for use in heavy-duty diesel engines comprise detergents at from about 0.1 to about 10 mass %, alternately from about 0.5 to about 7.5 mass %, alternately from about 1 to about 6.5 mass %, based on the lubricating composition.

[0321] Typically, lubricating compositions formulated for use in a passenger-car engines comprise detergents at from about 0.1 to about 10 mass %, alternately from about 0.5 to about 7.5 mass %, alternately from about 1 to about 6.5 mass %, based on the lubricating composition.

[0322] Typically, lubricating compositions formulated for use in a drive train (*e.g.*, transmissions) comprise detergents at from about 0.1 to about 10 mass %, alternately from about 0.5 to about 7.5 mass %, alternately from about 2 to about 6.5 mass %, based on the lubricating composition.

D. Friction Modifiers

[0323] A friction modifier is any material or materials that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid-containing such material(s). Friction modifiers, also known as friction reducers, or lubricity agents or oiliness agents, and other such agents that change the ability of base oils, formulated lubricating compositions, or functional fluids, to modify the coefficient of friction of a lubricated surface may be effectively used in combination with the base oils or lubricating compositions of the present disclosure if desired. Friction modifiers that lower the coefficient of friction are particularly advantageous in combination with the base oils and lubricating compositions of this disclosure.

[0324] Illustrative friction modifiers may include, for example, organometallic compounds or materials, or mixtures thereof. Illustrative organometallic friction modifiers useful in the lubricating oil formulations of this disclosure include, for example, tungsten and/or molybdenum compounds, such as molybdenum amine, molybdenum diamine, an organotungstenate, a molybdenum dithiocarbamate, molybdenum dithiophosphates, molybdenum amine complexes, molybdenum carboxylates, and the like, and mixtures thereof. Examples of useful molybdenum-containing compounds may conveniently include

molybdenum dithiocarbamates, trinuclear molybdenum compounds, for example, as described in PCT Publication No. WO 98/26030, sulfides of molybdenum and molybdenum dithiophosphate.

[0325] Other known friction modifiers comprise oil-soluble organo-molybdenum compounds. Such organo-molybdenum friction modifiers may also provide antioxidant and antiwear credits to a lubricating oil composition. Examples of such oil-soluble organo-molybdenum compounds include dithiocarbamates, dithiophosphates, dithiophosphinates, xanthates, thioxanthates, sulfides, and the like, and mixtures thereof. Particularly preferred are molybdenum dithiocarbamates, dialkyldithiophosphates, alkyl xanthates and alkylthioxanthates.

[0326] Additionally, the molybdenum compound may be an acidic molybdenum compound. These compounds will react with a basic nitrogen compound as measured by ASTM test D664 or D2896 titration procedure and are typically hexavalent. Included are molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdate, and other alkali metal molybdates and other molybdenum salts, *e.g.*, hydrogen sodium molybdate, MoOC_{14} , MoO_2Br_2 , $\text{Mo}_2\text{O}_3\text{C}_{16}$, molybdenum trioxide or similar acidic molybdenum compounds.

[0327] Among the molybdenum compounds useful in the compositions of this disclosure are organo-molybdenum compounds of the formula $\text{Mo}(\text{R}''\text{OCS}_2)_4$ and $\text{Mo}(\text{R}''\text{SCS}_2)_4$, wherein R'' is an organo group selected from the group consisting of alkyl, aryl, aralkyl and alkoxyalkyl, generally of from 1 to 30 carbon atoms, and preferably 2 to 12 carbon atoms and most preferably alkyl of 2 to 12 carbon atoms. Especially preferred are the dialkyldithiocarbamates of molybdenum.

[0328] Another group of organo-molybdenum compounds useful in the lubricating compositions of this disclosure are trinuclear molybdenum compounds, especially those of the formula Mo_3SkLnQz and mixtures thereof wherein the L are independently selected ligands having organo groups with a sufficient number of carbon atoms to render the compound soluble or dispersible in the oil, n is from 1 to 4, k varies from 4 to 7, Q is selected from the group of neutral electron-donating compounds such as water, amines, alcohols, phosphines, and ethers, and z ranges from 0 to 5 and includes non-stoichiometric values. At least 21 carbon atoms should be present among all the ligand/organo groups, such as at least 25, at least 30, or at least 35, carbon atoms.

[0329] Lubricating oil compositions useful in all aspects of the present disclosure preferably contain at least 10 ppm, at least 30 ppm, at least 40 ppm and more preferably at least

50 ppm molybdenum. Suitably, lubricating oil compositions useful in all aspects of the present disclosure contain no more than 1000 ppm, no more than 750 ppm, or no more than 500 ppm of molybdenum. Lubricating oil compositions useful in all aspects of the present disclosure preferably contain from 10 to 1000, such as 30 to 750 or 40 to 500, ppm of molybdenum (measured as atoms of molybdenum).

[0330] For more information or useful friction modifiers containing Mo, please see US Patent No. 10,829,712 (col 8, ln 58 to col 11, ln 31).

[0331] Ashless friction modifiers may be present in the lubricating oil compositions of the present disclosure and are known generally and include esters formed by reacting carboxylic acids and anhydrides with alkanols and amine-based friction modifiers. Other useful friction modifiers generally include a polar terminal group (*e.g.*, carboxyl or hydroxyl) covalently bonded to an oleophilic hydrocarbon chain. Esters of carboxylic acids and anhydrides with alkanols are described in US Patent No. 4,702,850. Examples of other conventional organic friction modifiers are described by M. Belzer in the "Journal of Tribology" (1992), Vol. 114, pp. 675-682 and M. Belzer and S. Jahanmir in "Lubrication Science" (1988), Vol. 1, pp. 3-26. Typically, the total amount of organic ashless friction modifier in a lubricant according to the present disclosure does not exceed 5 mass %, based on the total mass of the lubricating oil composition and preferably does not exceed 2 mass % and more preferably does not exceed 0.5 mass %.

[0332] Illustrative friction modifiers useful in the lubricating compositions described herein include, for example, alkoxylated fatty acid esters, alkanolamides, polyol fatty acid esters, borated glycerol fatty acid esters, fatty alcohol ethers, and mixtures thereof.

[0333] Illustrative alkoxylated fatty acid esters include, for example, polyoxyethylene stearate, fatty acid polyglycol ester, and the like. These can include polyoxypropylene stearate, polyoxybutylene stearate, polyoxyethylene isostearate, polyoxypropylene isostearate, polyoxyethylene palmitate, and the like.

[0334] Illustrative alkanolamides include, for example, lauric acid diethylalkanolamide, palmitic acid diethylalkanolamide, and the like. These can include oleic acid diethylalkanolamide, stearic acid diethylalkanolamide, oleic acid diethylalkanolamide, polyethoxylated hydrocarbylamides, polypropoxylated hydrocarbylamides, and the like.

[0335] Illustrative polyol fatty acid esters include, for example, glycerol monooleate, saturated mono-, di-, and tri-glyceride esters, glycerol monostearate, and the like. These can include polyol esters, hydroxyl-containing polyol esters, and the like.

[0336] Illustrative borated glycerol fatty acid esters include, for example, borated glycerol monooleate, borated saturated mono-, di-, and tri-glyceride esters, borated glycerol monostearate, and the like. In addition to glycerol polyols, these can include trimethylolpropane, pentaerythritol, sorbitan, and the like. These esters can be polyol monocarboxylate esters, polyol dicarboxylate esters, and on occasion polyoltricarboxylate esters. Preferred can be the glycerol monooleates, glycerol di-oleates, glycerol tri-oleates, glycerol mono-oleates, glycerol di-stearates, and glycerol tri-stearates and the corresponding glycerol mono-palmitates, glycerol di-palmitates, and glycerol tri-palmitates, and the respective isostearates, linoleates, and the like. Ethoxylated, propoxylated, and/or butoxylated fatty acid esters of polyols, especially using glycerol as underlying polyol are useful herein.

[0337] Illustrative fatty alcohol ethers include, for example, stearyl ether, myristyl ether, and the like. Alcohols, including those that have carbon numbers from C₃ to C₅₀, can be ethoxylated, propoxylated, or butoxylated to form the corresponding fatty alkyl ethers. The underlying alcohol portion can preferably be stearyl, myristyl, C₁₁-C₁₃ hydrocarbon, oleyl, isosteryl, and the like.

[0338] Useful concentrations of friction modifiers may range from 0.01 wt % to 5 wt %, or about 0.01 wt % to about 2.5 wt %, or about 0.05 wt % to about 1.5 wt %, or about 0.051 wt % to about 1 wt %. Concentrations of molybdenum-containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from 25 ppm to 700 ppm or more, and often with a preferred range of 50-200 ppm. Friction modifiers of all types may be used alone or in mixtures with the materials of this disclosure. Often mixtures of two or more friction modifiers, or mixtures of friction modifier(s) with alternate surface-active material(s), are also desirable. For example, combinations of Mo-containing compounds with polyol fatty acid esters, such as glycerol mono-oleate are useful herein.

E. Antioxidants

[0339] Antioxidants retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, a viscosity increase in a lubricant, and the like. A wide variety of oxidation inhibitors that are useful in lubricating oil compositions. See *Lubricants and Related Products*, Klamann, Wiley VCH, 1984; US Patent Nos. 4,798,684 and 5,084,197, for example.

[0340] Useful antioxidants include hindered phenols. These phenolic antioxidants may be ashless (metal-free) phenolic compounds or neutral or basic metal salts of certain phenolic compounds. Typical phenolic antioxidant compounds are the hindered phenolics, which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy

aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic antioxidants include the hindered phenols substituted with C₆₊ alkyl groups and the alkylene coupled derivatives of these hindered phenols. Examples of phenolic materials of this type 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; and 2-methyl-6-t-butyl-4-dodecyl phenol. Other useful hindered mono-phenolic antioxidants may include, for example, hindered 2,6-di-alkyl-phenolic propionic ester derivatives. Bis-phenolic antioxidants may also be advantageously used herein. Examples of ortho-coupled phenols include: 2,2'-bis(4-heptyl-6-t-butyl-phenol); 2,2'-bis(4-octyl-6-t-butyl-phenol); and 2,2'-bis(4-dodecyl-6-t-butyl-phenol). Para-coupled bisphenols include, for example, 4,4'-bis(2,6-di-t-butyl-phenol) and 4,4'-methylene-bis(2,6-di-t-butyl-phenol).

[0341] Effective amounts of one or more catalytic antioxidants may also be used. The catalytic antioxidants comprise an effective amount of a) one or more oil soluble polymetal organic compounds; and, effective amounts of b) one or more substituted N,N'-diaryl-o-phenylenediamine compounds or c) one or more hindered phenol compounds; or a combination of both b) and c). Catalytic antioxidants useful herein are more fully described in US Patent No. 8,048,833.

[0342] Non-phenolic oxidation inhibitors, which may be used include aromatic amine antioxidants and these may be used either as such or in combination with phenolics. Typical examples of non-phenolic antioxidants include: alkylated and non-alkylated aromatic amines such as aromatic monoamines of the formula R₈R₉R₁₀N, where R₈ is an aliphatic, aromatic or substituted aromatic group, R₉ is an aromatic or a substituted aromatic group, and R₁₀ is H, alkyl, aryl or R₁₁S(O)XR₁₂ where R₁₁ is an alkylene, alkenylene, or aralkylene group, R₁₂ is an alkyl group, or an alkenyl, aryl, or alkaryl group, and x is 0, 1, or 2. The aliphatic group R₈ may contain from 1 to about 20 carbon atoms, and preferably contains from about 6 to 12 carbon atoms. The aliphatic group is typically a saturated aliphatic group. Preferably, both R₈ and R₉ are aromatic or substituted aromatic groups, and the aromatic group may be a fused ring aromatic group such as naphthyl. Aromatic groups R₈ and R₉ may be joined together with other groups such as S.

[0343] Typical aromatic amines antioxidants have alkyl substituent groups of at least about 6 carbon atoms. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl, and decyl. Generally, the aliphatic groups will not contain more than about 14 carbon atoms. The general types of amine antioxidants useful in the present compositions include diphenylamines, phenyl naphthylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures

of two or more aromatic amines are also useful. Polymeric amine antioxidants can also be used. Particular examples of aromatic amine antioxidants useful in the present disclosure include: p,p'-dioctyldiphenylamine; t-octylphenyl-alpha-naphthylamine; phenyl-alpha-naphthylamine; and p-octylphenyl-alpha-naphthylamine.

[0344] Sulfur-containing antioxidants are also useful herein. In particular, one or more oil-soluble or oil-dispersible sulfur-containing antioxidant(s) can be used as an antioxidant additive. For example, sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof also are useful antioxidants herein. Suitably, the lubricating oil composition(s) of the present disclosure may include the one or more sulfur-containing antioxidant(s) in an amount to provide the lubricating oil composition with from 0.02 to 0.2, preferably from 0.02 to 0.15, even more preferably 0.02 to 0.1, even more preferably 0.04 to 0.1, mass % sulfur based on the total mass of the lubricating oil composition. Optionally the oil-soluble or oil-dispersible sulfur-containing antioxidant(s) are selected from sulfurized C₄ to C₂₅ olefin(s), sulfurized aliphatic (C₇ to C₂₉) hydrocarbyl fatty acid ester(s), ashless sulfurized phenolic antioxidant(s), sulfur-containing organo-molybdenum compound(s), and combinations thereof. For further information, on sulfurized materials useful as antioxidants herein, please see US Patent No. 10,731,101 (col 15, ln 55 to col 22, ln 12).

[0345] Antioxidants useful herein include hindered phenols and/or arylamines. These antioxidants may be used individually by type or in combination with one another.

[0346] Typical antioxidants include: Irganox™ L67, Ethanox™ 4702, Lanxess Additin™ RC 7110; Ethanox™ 4782J; Irganox™ 1135, Irganox™ 5057, sulfurized lard oil and palm oil fatty acid methyl ester.

[0347] Antioxidant additives may be used in an amount of about 0.01 to 10 (alternately 0.01 to 5, alternately 0.01 to 3) wt %, alternately about 0.03 to 5 wt %, alternately 0.05 to less than 3 wt %, based upon the weight of the lubricating composition.

[0348] Compositions according to the present disclosure may contain an additive having a different enumerated function that also has secondary effects as an antioxidant (for example, phosphorus-containing antiwear agents (such as ZDDP) may also have antioxidant effects). These additives are not included as antioxidants for purposes of determining the amount of antioxidant in a lubricating oil composition or concentrate herein.

F. Pour Point Depressants

[0349] Conventional pour point depressants (also known as lube oil flow improvers) may be added to the compositions of the present disclosure if desired. These pour point depressants may be added to lubricating compositions of the present disclosure to lower the minimum

temperature at which the fluid will flow or can be poured. Examples of suitable pour point depressants include polymethacrylates, polyacrylates, polyarylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty acids and allyl vinyl ethers. US Patent Nos. 1,815,022; 2,015,748; 2,191,498; 2,387,501; 2,655,479; 2,666,746; 2,721,877; 2,721,878; and 3,250,715 describe useful pour point depressants and/or the preparation thereof. Such additives may be used in an amount of about 0.01 to 5 wt %, preferably about 0.01 to 1.5 wt %, based upon the weight of the lubricating composition.

G. Anti-Foam Agents

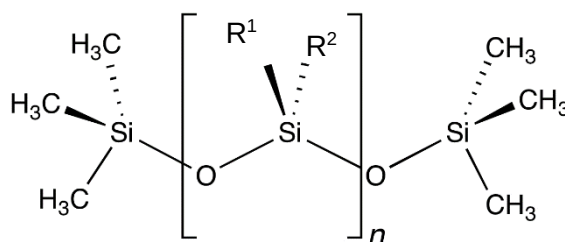
[0350] Anti-foam agents may advantageously be added to lubricant compositions described herein. These agents prevent or retard the formation of stable foams. Silicones and/or organic polymers are typical anti-foam agents. For example, polysiloxanes, such as silicon oil or polydimethyl siloxane, provide anti-foam properties.

[0351] Anti-foam agents are commercially available and may be used in minor amounts such as 5 wt % or less, 3 wt % or less, 1 wt % or less, 0.1 wt % or less, such as from 5 to wt % to 0.1 ppm such as from 3 wt % to 0.5 ppm, such as from 1 wt % to 10 ppm.

[0352] For example, it may be that the lubricating oil composition comprises an anti-foam agent comprising polyalkyl siloxane, such as a polydialkyl siloxane, for example, wherein the alkyl is a C₁-C₁₀ alkyl group, *e.g.*, a polydimethylsiloxane (PDMS), also known as a silicone oil. Alternately, the siloxane is a poly(R³)siloxane, wherein R³ is one or more same or different linear branched or cyclic hydrocarbyls, such as alkyls or aryls, typically having 1 to 20 carbon atoms. It may be that, for example, the lubricating oil composition comprises a polymeric siloxane compound according to Formula 1 below wherein R¹ and R² are independently methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl or decyl, phenyl, naphthyl, alkyl substituted phenyl, or isomers thereof (such as methyl, phenyl) and n is from 2 to 1000, such as 50 to 450, alternately such as 40 to 100.

[0353] Additionally, or alternatively, it may be that the lubricating oil composition comprises an organo-modified siloxane (OMS), such as a siloxane modified with an organo group such as a polyether (*e.g.*, ethylene-propyleneoxide copolymer), long chain hydrocarbyl (*e.g.*, C₁₁-C₁₀₀ alkyl), or aryl (*e.g.*, C₆-C₁₄ aryl). It may be that, for example, the lubricating oil composition comprises an organo-modified siloxane compound according to Formula 1, wherein n is from 2 to 2000, such as 50 to 450 (alternately such as 40 to 100), and wherein R¹ and R² are the same or different, optionally wherein each of R¹ and R² is, independently an organo group, such as an organo group selected from polyether (*e.g.*, ethylene-propyleneoxide

copolymer), long chain hydrocarbyl (*e.g.*, C₁₁-C₁₀₀ alkyl), or aryl (*e.g.*, C₆-C₁₄ aryl). Preferably, one of R¹ and R² is CH₃.



Formula 1

[0354] Based on the total weight of the lubricant composition, the siloxane according to Formula 1 is incorporated so as to provide about 0.1 to less than about 30 ppm Si, or about 0.1 to about 25 ppm Si, or about 0.1 to about 20 ppm Si, or about 0.1 to about 15 ppm Si, or about 0.1 to about 10 ppm Si. More preferably, it is in the range of about 3-10 ppm Si.

[0355] In embodiments, silicone anti-foam agents useful herein are available from Dow Corning Corporation and Union Carbide Corporation, such as Dow Corning FS-1265 (1000 centistokes), Dow Corning DC-200, and Union Carbide UC-L45. Silicone anti-foamants useful herein include polydimethylsiloxane, phenyl-methyl polysiloxane, linear, cyclic or branched siloxanes, silicone polymers and copolymers, and/or organo-silicone copolymers. Also, a siloxane polyether copolymer Anti-foamant available from OSI Specialties, Inc. of Farmington Hills, Michigan and may be substituted or included. One such material is sold as SILWET-L-7220.

[0356] Acrylate polymer anti-foam agent can also be used herein. Typical acrylate anti-foamants include polyacrylate anti-foamant available from Monsanto Polymer Products Co. known as PC-1244. A preferred acrylate polymer anti-foam agent useful herein is PXTM3841 (*i.e.*, an alkyl acrylate polymer), commercially available from Dorf Kettl, also referred to as MobiladTMC402.

[0357] In embodiments, a combination of silicone anti-foamant and acrylate anti-foamant can be used, such as at a weight ratio of the silicone anti-foamant to the acrylate anti-foamant of from about 5:1 to about 1:5, see, for example, US Patent Application Publication No. 2021/0189283.

H. Viscosity Modifiers

[0358] Viscosity modifiers (also referred to as viscosity index improvers or viscosity improvers) can be included in the lubricating compositions described herein. Viscosity modifiers provide lubricants with high and low temperature operability. These additives impart

shear stability at elevated temperatures and acceptable viscosity at low temperatures. Suitable viscosity modifiers include high molecular weight hydrocarbons, polyesters, and viscosity modifier dispersants that can function as both a viscosity modifier and a dispersant. Typical molecular weights of these polymers are between about 10,000 to 1,500,000 g/mol, more typically about 20,000 to 1,200,000 g/mol, and even more typically between about 50,000 and 1,000,000 g/mol.

[0359] Examples of suitable viscosity modifiers are linear or star-shaped polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a commonly used viscosity modifier. Another suitable viscosity modifier is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example), some formulations of which also serve as pour point depressants. Other suitable viscosity modifiers include copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, and polyacrylates (copolymers of various chain length acrylates, for example). Specific examples include styrene-isoprene or styrene-butadiene based polymers of 50,000 to 200,000 g/mol molecular weight.

[0360] Copolymers useful as viscosity modifiers include those commercially available from Chevron Oronite Company LLC under the trade designation "PARATONE™" (such as "PARATONE™ 8921," "PARATONE™ 68231," and "PARATONE™ 8941"); from Afton Chemical Corporation under the trade designation "HiTEC™" (such as HiTEC™ 5850B, and HiTEC™5777); and from The Lubrizol Corporation under the trade designation "Lubrizol™ 7067C". Hydrogenated polyisoprene star polymers useful as viscosity modifiers herein include those commercially available from Infineum International Limited, *e.g.*, under the trade designation "SV200™" and "SV600™". Hydrogenated diene-styrene block copolymers useful as viscosity modifiers herein are commercially available from Infineum International Limited, *e.g.*, under the trade designation "SV 50™".

[0361] Polymers useful as viscosity modifiers herein include polymethacrylate or polyacrylate polymers, such as linear polymethacrylate or polyacrylate polymers, such as those available from Evnoik Industries under the trade designation "Viscoplex™" (*e.g.*, Viscoplex™ 6-954) or star polymers which are available from Lubrizol Corporation under the trade designation Asteric™ (*e.g.*, Lubrizol™ 87708 and Lubrizol™ 87725).

[0362] Vinyl aromatic-containing polymers useful as viscosity modifiers herein may be derived from vinyl aromatic hydrocarbon monomers, such as styrenic monomers, such as styrene. Illustrative vinyl aromatic-containing copolymers useful herein may be represented by the following general formula: A-B wherein A is a polymeric block derived predominantly

from vinyl aromatic hydrocarbon monomer (such as styrene), and B is a polymeric block derived predominantly from conjugated diene monomer (such as isoprene).

[0363] Vinyl aromatic-containing polymers useful as viscosity modifiers may have a Kinematic viscosity at 100° C of 20 cSt or less, such as 15 cSt or less, such as 12 cSt or less, but may be diluted (such as in Group I, II, and/or III basestock) to higher Kinematic viscosities at 100° C, such as to 40 cSt or more, such as 100 cSt or more, such as 1000 cSt or more, such as 1000 to 2000 cSt.).

[0364] Typically, the viscosity modifiers may be used in an amount of about 0.01 to about 10 wt %, such as about 0.1 to about 7 wt %, such as 0.1 to about 4 wt %, such as about 0.2 to about 2 wt %, such as about 0.2 to about 1 wt %, and such as about 0.2 to about 0.5 wt %, based on the total weight of the formulated lubricant composition.

[0365] Viscosity modifiers are typically added as concentrates, in large amounts of diluent oil. The "as delivered" viscosity modifier typically contains from 20 wt % to 75 wt % of an active polymer for polymethacrylate or polyacrylate polymers, or from 8 wt % to 20 wt % of an active polymer for olefin copolymers, hydrogenated polyisoprene star polymers, or hydrogenated diene-styrene block copolymers, in the "as delivered" polymer concentrate.

I. Dispersants

[0366] During engine operation, oil-insoluble oxidation byproducts are produced. Dispersants help keep these byproducts in solution, thus diminishing their deposition on metal surfaces. Dispersants used in the formulation of the lubricating compositions herein may be ashless or ash-forming in nature. Preferably, the dispersant is ashless. So called ashless dispersants are organic materials that form substantially no ash upon combustion. For example, non-metal-containing or borated metal-free dispersants are considered ashless. In contrast, metal-containing detergents tend to form ash upon combustion.

[0367] Dispersants useful herein typically contain a polar group attached to a relatively high molecular weight hydrocarbon chain. The polar group typically contains at least one element of nitrogen, oxygen, or phosphorus. Typical hydrocarbon chains contain 40 to 500, such as 50 to 400 carbon atoms.

Dispersants of (Poly)alkenylsuccinic derivatives

[0368] A particularly useful class of dispersants includes the (poly)alkenylsuccinic derivatives, typically produced by the reaction of a long chain hydrocarbyl-substituted succinic compound, usually a hydrocarbyl-substituted succinic anhydride, with a polyhydroxy or polyamino compound. The long chain hydrocarbyl group constituting the oleophilic portion of the molecule which confers solubility in the oil, is often a polyisobutylene group (typically

the long chain hydrocarbyl group, such as a polyisobutylene group, has an Mn of 400 to 3000 g/mol, such as 450 to 2500 g/mol). Many examples of this type of dispersant are well known commercially and in the literature. Exemplary US Patents describing such dispersants include US Patent Nos. 3,172,892; 3,2145,707; 3,219,666; 3,316,177; 3,341,542; 3,444,170; 3,454,607; 3,541,012; 3,630,904; 3,632,511; 3,787,374 and 4,234,435. Other types of dispersants are described in US Patent Nos. 3,036,003; 3,200,107; 3,254,025; 3,275,554; 3,438,757; 3,454,555; 3,565,804; 3,413,347; 3,697,574; 3,725,277; 3,725,480; 3,726,882; 4,454,059; 3,329,658; 3,449,250; 3,519,565; 3,666,730; 3,687,849; 3,702,300; 4,100,082; 5,705,458. A further description of dispersants useful herein may be found, for example, in European Patent Applications Nos. 0 471 071 and 0 451 380, to which reference is made for this purpose.

[0369] Hydrocarbyl-substituted succinic acid and hydrocarbyl-substituted succinic anhydride derivatives are useful dispersants. In particular, succinimide, succinate esters, or succinate ester amides prepared by the reaction of a hydrocarbon-substituted succinic acid or anhydride compound (typically having at least 25 carbon atoms, such as 28 to 400 carbon atoms, in the hydrocarbon substituent), with at least one equivalent of a polyhydroxy or polyamino compound (such as an alkylene amine) are particularly useful herein. Hydrocarbyl-substituted succinic acid and hydrocarbyl-substituted succinic anhydride derivatives may have a number average molecular weight of at least 400 g/mol, such as at least 900 g/mol, such as at least 1500 g/mol, such as from 400 to 4000 g/mol, such as from 800 to 3000, such as from 2000 to 2800 g/mol, such from about 2100 to 2500 g/mol, and such as from about 2200 to about 2400 g/mol.

[0370] Succinimides, which are particularly useful herein, are formed by the condensation reaction between: 1) hydrocarbyl-substituted succinic anhydrides, such as polyisobutylene succinic anhydride (PIBSA); and 2) polyamine (PAM). Examples of suitable polyamines include: polyhydrocarbyl polyamines, polyalkylene polyamines, hydroxy-substituted polyamines, polyoxyalkylene polyamines, and combinations thereof. Examples of polyamines include tetraethylene pentamine, pentaethylene hexamine, tetraethylenepentamine (TEPA), pentaethylenhexamine (PEHA), N-phenyl-p-phenylenediamine (ADPA), and other polyamines having an average of 5, 6, 7, 8, or 9 nitrogen atoms per molecule. Mixtures where the average number of nitrogen atoms per polyamine molecule is greater than 7 are commonly called heavy polyamines or H-PAMs and may be commercially available under trade names such as HPA™ and HPA-X™ from DowChemical, E-100™ from Huntsman Chemical, et al. Examples of hydroxy-substituted polyamines include N-hydroxyalkyl-alkylene polyamines such as N-(2-hydroxyethyl)ethylene diamine, N-(2-hydroxyethyl)piperazine, and/or N-hydroxyalkylated alkylene diamines of the type described, for example, in US Patent No.

4,873,009. Examples of polyoxyalkylene polyamines include polyoxyethylene and/or polyoxypropylene diamines and triamines (as well as co-oligomers thereof) having an average Mn from about 200 to about 5000 g/mol. Products of this type are commercially available under the tradename Jeffamine™. Representative examples of useful succinimides are shown in US Patent Nos. 3,087,936; 3,172,892; 3,219,666; 3,272,746; 3,322,670; 3,652,616; 3,948,800; and 6,821,307; and CA Patent No. 1,094,044.

[0371] The dispersants may comprise one or more, optionally borated, higher molecular weight (Mn 1600 g/mol or more, such as 1800 to 3000 g/mol) succinimides and one or more, optionally borated, lower molecular weight (Mn less than 1600 g/mol) succinimides, where the higher molecular weight may be 1600 to 3000 g/mol, such as 1700 to 2800 g/mol, such as 1800 to 2500 g/mol, such as 1850 to 2300 g/mol; and the lower molecular weight may be 600 to less than 1600 g/mol, such as 650 to 1500 g/mol, such as 700 to 1400 g/mol, such as 800 to 1300 g/mol, such as 850 to 1200 g/mol such as 900 to 1150 g/mol, such as 900 to 1000 g/mol. The higher molecular weight succinimide dispersant may be present in the lubricating composition in an amount of from 0.5 to 10 wt %, or from 0.8 to 6 wt %, or from 1.0 to 5 wt %, or from 1.5 to 5 wt %, or from 1.5 to 4.0 wt %; and the lower molecular weight succinimides dispersant may be present in the lubricating composition in an amount of from 1 to 5 wt %, or from 1.5 to 4.8 wt %, or from 1.8 to 4.6 wt %, or from 1.9 to 4.6 wt %, or at 2 wt % or more, such as 2 to 5 wt %. The lower molecular weight succinimides may differ from the higher molecular weight succinimides, by 500 g/mol or more, such as by 750 g/mol or more, such as by 1000 g/mol or more, such as by 1200 g/mol or more, such as by 500 to 3000 g/mol, such as by 750 to 2000 g/mol, such as by 1000 to 1500 g/mol.

[0372] Succinate esters useful as dispersants include those formed by the condensation reaction between hydrocarbyl-substituted succinic anhydrides and alcohols or polyols. For example, the condensation product of a hydrocarbyl-substituted succinic anhydride and pentaerythritol is a useful dispersant.

[0373] Succinate ester amides useful herein are formed by a condensation reaction between hydrocarbyl-substituted succinic anhydrides and alkanol amines. Suitable alkanol amines include ethoxylated polyalkylpolyamines, propoxylated polyalkylpolyamines, and polyalkenylpolyamines such as polyethylene polyamines and/or propoxylated hexamethylenediamine. Representative examples are shown in US Patent No. 4,426,305.

[0374] Hydrocarbyl-substituted succinic anhydrides (such as PIBSA) esters of hydrocarbyl bridged aryloxy alcohols are also useful as dispersants herein. For information on such dispersants, please see US Patent No. 7,485,603, particularly, col 2, ln 65 to col 6, ln 22 and

col 23, ln 40 to col 26, ln 46. In particular, PIBSA esters of methylene-bridged naphthyloxy ethanol (*i.e.*, 2-hydroxyethyl-1-naphthol ether (or hydroxy-terminated ethylene oxide oligomer ether of naphthol) are useful herein.

[0375] The molecular weight of the hydrocarbyl-substituted succinic anhydrides used in the preceding paragraphs will typically range from 350 to 4000 g/mol, such as 400 to 3000 g/mol, such as 450 to 2800 g/mol, such as 800 to 2500 g/mol. The above (poly)alkenylsuccinic derivatives can be post-reacted with various reagents such as sulfur, oxygen, formaldehyde, carboxylic acids such as oleic acid.

[0376] The dispersants may be present in the lubricant in an amount 0.1 mass % to 20 mass % of the composition, such as 0.2 to 15 mass %, such as 0.25 to 10 mass %, such as 0.3 to 5 mass %, such as 1.0 mass % to 3.0 mass %, of the lubricating oil composition.

[0377] The above (poly)alkenylsuccinic derivatives, can also be post reacted with boron compounds such as boric acid, borate esters or highly borated dispersants, to form borated dispersants generally having from about 0.1 to about 5 moles of boron per mole of dispersant reaction product.

[0378] Dispersants useful herein include borated succinimides, including those derivatives from mono-succinimides, bis-succinimides, and/or mixtures of mono- and bis-succinimides, wherein the hydrocarbyl succinimide is derived from a hydrocarbylene group such as polyisobutylene having an Mn of from about 300 to about 5000 g/mol, or from about 500 to about 3000 g/mol, or about 1000 to about 2000 g/mol, or a mixture of such hydrocarbylene groups, often with high terminal vinylic groups.

[0379] The boron-containing dispersant may be present at 0.01 wt % to 20 wt %, or 0.1 wt % to 15 wt %, or 0.1 wt % to 10 wt %, or 0.5 wt % to 8 wt %, or 1.0 wt % to 6.5 wt %, or 0.5 wt % to 2.2 wt % of the lubricating composition.

[0380] The boron-containing dispersant may be present in an amount to deliver boron to the composition at 15 ppm to 2000 ppm, or 25 ppm to 1000 ppm, or 40 ppm to 600 ppm, or 80 ppm to 350 ppm.

[0381] The borated dispersant may be used in combination with non-borated dispersant and may be the same or different compound as the non-borated dispersant. In one embodiment, the lubricating composition may include one or more boron-containing dispersants and one or more non-borated dispersants, wherein the total amount of dispersant may be 0.01 wt % to 20 wt %, or 0.1 wt % to 15 wt %, or 0.1 wt % to 10 wt %, or 0.5 wt % to 8 wt %, or 1.0 wt % to 6.5 wt %, or 0.5 wt % to 2.2 wt % of the lubricating composition and wherein the ratio of

borated dispersant to non-borated dispersant may be 1:10 to 10:1 (weight:weight) or 1:5 to 3:1 or 1:3 to 2:1.

[0382] The dispersant may comprise one or more borated or unborated poly(alkenyl)succinimides, where the polyalkenyl is derived from polyisobutylene and the imide is derived from a polyamine ("PIBSA-PAM").

[0383] The dispersant may comprise one or more PIBSA-PAMs, where the PIB is derived from polyisobutylene having an Mn of from 600 to 5000, such as from 700 to 4000, such as from 800 to 3000, such as from 900 to 2500 g/mol and the polyamine is derived from hydrocarbyl-substituted polyamines, such as tetraethylene pentamine, pentaethylene hexamine, tetraethylenepentamine (TEPA), pentaethylenhexamine (PEHA), N-phenyl-p-phenylenediamine (ADPA), and other polyamines having an average of 5, 6, 7, 8, or 9 nitrogen atoms per molecule). The dispersant may be borated, typically at levels of up to 4 mass % such as from 1 to 3 mass %. The dispersant may comprise one or more borated and one or more non-borated PIBSA-PAM's. The dispersant may comprise one or more borated PIBSA-PAM's derived from a PIB having an Mn of 700 to 1800 g/mol (such as 800 to 1500 g/mol) and one or more non-borated PIBSA-PAM's derived from a PIB having an Mn of more than 1800 to 5000 g/mol (such as 2000 to 3000 g/mol). The dispersant may comprise one or more non-borated PIBSA-PAM's derived from a PIB having an Mn of 700 to 1800 g/mol (such as 800 to 1500 g/mol) and one or more borated PIBSA-PAM's derived from a PIB having an Mn of more than 1800 to 5000 g/mol (such as 2000 to 3000 g/mol).

[0384] The dispersant may comprise PIBSA derived from a PIB having an Mn of 700 to 5000 g/mol (such as 800 to 3000 g/mol) and one or more borated or non-borated PIBSA-PAM's derived from a PIB having an Mn of 700 to 5000 g/mol.

[0385] The dispersant may comprise PIBSA derived from a PIB having an Mn of 700 to 5000 g/mol (such as 800 to 3000 g/mol) and one or more borated PIBSA-PAM's derived from a PIB having an Mn of 700 to 1800 g/mol (such as 800 to 1500 g/mol) and one or more non-borated PIBSA-PAM's derived from a PIB having an Mn of more than 1800 to 5000 g/mol (such as 2000 to 3000 g/mol). The dispersant may comprise PIBSA derived from a PIB having an Mn of 700 to 5000 g/mol (such as 800 to 3000 g/mol) one or more non-borated PIBSA-PAM's derived from a PIB having an Mn of 700 to 1800 g/mol (such as 800 to 1500 g/mol) and one or more borated PIBSA-PAM's derived from a PIB having an Mn of more than 1800 to 5000 g/mol (such as 2000 to 3000 g/mol).

[0386] The dispersant may comprise one or more borated or non-borated PIBSA-PAM's and one or more PIBSA-esters of hydrocarbyl bridged aryloxy alcohols.

[0387] The dispersant may comprise one or more borated and one or more non-borated PIBSA-PAM's.

[0388] The dispersant may comprise one or more, optionally borated, higher molecular weight (M_n 1600 g/mol or more, such as 1800 to 3000 g/mol) PIBSA-PAM's and one or more, optionally borated, lower molecular weight (M_n less than 1600 g/mol) PIBSA-PAM's, where the higher molecular weight may be 1600 to 3000 g/mol, such as 1700 to 2800 g/mol, such as 1800 to 2500 g/mol, such as 1850 to 2300 g/mol; and the lower molecular weight may be 600 to less than 1600 g/mol, such as 650 to 1500 g/mol, such as 700 to 1400 g/mol, such as 800 to 1300 g/mol, such as 850 to 1200 g/mol, such as 900 to 11500 g/mol, such as 900 to 100 g/mol. The higher molecular weight PIBSA-PAM dispersant may be present in the lubricating composition in an amount of from 0.5 to 10 wt %, or from 0.8 to 6 wt %, or from 1.0 to 5 wt %, or from 1.5 to 5 wt % or from 1.5 to 4.0 wt %; and the lower molecular weight PIBSA-PAM dispersant may be present in the lubricating composition in an amount of from 1 to 5 wt %, or from 1.5 to 4.8 wt %, or from 1.8 to 4.6 wt %, or from 1.9 to 4.6 wt %, or at 2 wt % or more, such as 2 to 5 wt %.

Dispersants of Mannich Bases

[0389] Mannich base dispersants useful herein are typically made from the reaction of an amine component, a hydroxy aromatic compound (substituted or unsubstituted, such as alkyl substituted), such as alkylphenols, and an aldehyde, such as formaldehyde. See US Patent Nos. 4,767,551 and 10,899,986. Process aids and catalysts, such as oleic acid and sulfonic acids, can also be part of the reaction mixture. Representative examples are shown in US Patent Nos. 3,697,574; 3,703,536; 3,704,308; 3,751,365; 3,756,953; 3,798,165; 3,803,039; 4,231,759; 9,938,479; 7,491,248; and 10,899,986, and PCT Publication No. WO 01/42399.

Dispersants of Polymethacrylate or Polyacrylate Derivatives

[0390] Polymethacrylate or polyacrylate derivatives are another class of dispersants useful herein. These dispersants are typically prepared by reacting a nitrogen-containing monomer and a methacrylic or acrylic acid esters containing 5-25 carbon atoms in the ester group. Representative examples are shown in US Patent Nos. 2,100,993, and 6,323,164. Polymethacrylate and polyacrylate dispersants are typically lower molecular weights.

[0391] The lubricating composition of the disclosure typically comprises dispersant at 0.1 mass % to 20 mass % of the composition, such as 0.2 to 15 mass %, such as 0.25 to 10 mass %, such as 0.3 to 5 mass %, such as 2.0 mass % to 4.0 mass % of the lubricating oil composition. Alternately the dispersant may be present at 0.1 wt % to 5 wt %, or 0.01 wt % to 4 wt % of the lubricating composition.

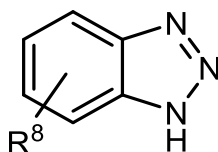
[0392] For further information on dispersants useful herein, please see US Patent No. 10,829,712, col 13, ln 36 to col 16, ln 67 and US Patent No. 7,485,603, col 2, ln 65 to col 6, ln 22, col 8, ln 25 to col 14, ln 53, and col 23, ln 40 to col 26, ln 46.

[0393] Compositions according to the present disclosure may contain an additive having a different enumerated function that also has secondary effects as a dispersant (for example, Component B Functionalized Polymer described above, may also have dispersant effects). These additives are not included as dispersants for purposes of determining the amount of dispersant in a lubricating oil composition or concentrate herein.

J. Corrosion Inhibitors/Anti-rust Agents

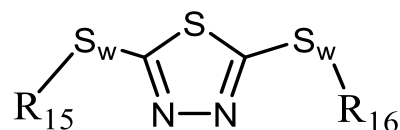
[0394] Corrosion inhibitors may be used to reduce the corrosion of metals and are often alternatively referred to as metal deactivators or metal passivators. Some corrosion inhibitors may alternatively be characterized as antioxidants.

[0395] Suitable corrosion inhibitors may include nitrogen and/or sulfur-containing heterocyclic compounds such as triazoles (*e.g.*, benzotriazoles), substituted thiadiazoles, imidazoles, thiazoles, tetrazoles, hydroxyquinolines, oxazolines, imidazolines, thiophenes, indoles, indazoles, quinolines, benzoxazines, dithiols, oxazoles, oxatriazoles, pyridines, piperazines, triazines and derivatives of any one or more thereof. A particular corrosion inhibitor is a benzotriazole represented by the structure:



wherein R^8 is absent (hydrogen) or is a C_1 to C_{20} hydrocarbyl or substituted hydrocarbyl group which may be linear or branched, saturated or unsaturated. It may contain ring structures that are alkyl or aromatic in nature and/or contain heteroatoms such as N, O, or S. Examples of suitable compounds may include benzotriazole, alkyl-substituted benzotriazoles (*e.g.*, tolyltriazole, ethylbenzotriazole, hexylbenzotriazole, octylbenzotriazole, etc.), aryl substituted benzotriazole, alkylaryl- or arylalkyl-substituted benzotriazoles, and the like, as well as combinations thereof. For instance, the triazole may comprise or be a benzotriazole and/or an alkylbenzotriazole in which the alkyl group contains from 1 to about 20 carbon atoms or from 1 to about 8 carbon atoms. Non-limiting examples of such corrosion inhibitors may comprise or be benzotriazole, tolyltriazole, and/or optionally, substituted benzotriazoles such as Irgamet™ 39, which is commercially available from BASF of Ludwigshafen, Germany. A preferred corrosion inhibitor may comprise or be benzotriazole and/or tolyltriazole.

[0396] Additionally, or alternatively, the corrosion inhibitor may include one or more substituted thiadiazoles represented by the structure:



wherein R₁₅ and R₁₆ are independently hydrogen or a hydrocarbon group, which group may be aliphatic or aromatic, including cyclic, alicyclic, aralkyl, aryl and alkaryl, and wherein each w is independently 1, 2, 3, 4, 5, or 6 (preferably 2, 3, or 4, such as 2). These substituted thiadiazoles are derived from the 2,5-dimercapto-1,3,4-thiadiazole (DMTD) molecule. Many derivatives of DMTD have been described in the art, and any such compounds may be included in the fluid used in the present disclosure. For example, US Patent Nos. 2,719,125; 2,719,126; and 3,087,937; describe the preparation of various 2, 5-bis-(hydrocarbon dithio)-1,3,4-thiadiazoles.

[0397] Further, additionally or alternatively, the corrosion inhibitor may include one or more other derivatives of DMTD, such as a carboxylic ester in which R₁₅ and R₁₆ may be joined to the sulfide sulfur atom through a carbonyl group. Preparation of these thioester-containing DMTD derivatives is described, for example, in US Patent No. 2,760,933. DMTD derivatives produced by condensation of DMTD with alpha-halogenated aliphatic carboxylic acids having at least 10 carbon atoms are described, for example, in US Patent No. 2,836,564. This process produces DMTD derivatives wherein R₁₅ and R₁₆ are HOOC-CH(R₁₉)-(R₁₉ being a hydrocarbyl group). DMTD derivatives further produced by amidation or esterification of these terminal carboxylic acid groups may also be useful.

[0398] The preparation of 2-hydrocarbyldithio-5-mercapto-1,3,4-thiadiazoles is described, for example, in US Patent No. 3,663,561.

[0399] A class of DMTD derivatives may include mixtures of a 2-hydrocarbyldithio-5-mercapto-1,3,4-thiadiazole and a 2,5-bis-hydrocarbyldithio-1,3,4-thiadiazole. Such mixtures may be sold under the tradename HiTEC™ 4313 and are commercially available from Afton Chemical Company.

[0400] The preparation of 2-hydrocarbyldithio-5-mercapto-1,3,4-thiadiazoles is described, for example, in US Patent No. 3,663,561.

[0401] A class of DMTD derivatives may include mixtures of a 2-hydrocarbyldithio-5-mercapto-1,3,4-thiadiazole and a 2,5-bis-hydrocarbyldithio-1,3,4-thiadiazole. Such mixtures may be sold under the tradename HiTEC™ 4313 and are commercially available from Afton Chemical Company.

[0402] Still further, additionally or alternatively, the corrosion inhibitor may include a trifunctional borate having the structure, $B(OR_{46})_3$, in which each R_{46} may be the same or different. As the borate may typically be desirably compatible with the non-aqueous medium of the composition, each R_{46} may, in particular, comprise or be a hydrocarbyl C_1 - C_8 moiety. For compositions in which the non-aqueous medium comprises or is a lubricating oil basestock, for example, better compatibility can typically be achieved when the hydrocarbyl moieties are each at least C_4 . Non-limiting examples of such corrosion inhibitors thus include, but are not limited to, triethylborate, tripropylborates such as triisopropylborate, tributylborates such as tri-tert-butylborate, tripentylborates, trihexylborates, trioctylborates such as tri-(2-ethylhexyl)borate, monohexyl dibutylborate, and the like, as well as combinations thereof.

[0403] When used, a corrosion inhibitor may comprise a substituted thiadiazole, a substituted benzotriazole, a substituted triazole, a trisubstituted borate, or a combination thereof.

[0404] When desired, corrosion inhibitors can be used in any effective amount, but, when used, may typically be used in amounts from about 0.001 wt % to 5.0 wt %, based on the weight of the composition, *e.g.*, from 0.005 wt % to 3.0 wt % or from 0.01 wt % to 1.0 wt %. Alternately, such additives may be used in an amount of about 0.01 to 5 wt %, preferably about 0.01 to 1.5 wt %, based upon the weight of the lubricating composition.

[0405] In some embodiments, 3,4-oxypyridinone-containing compositions may contain substantially no (*e.g.*, 0, or less than 0.001 wt %, 0.0005 wt % or less, not intentionally added, and/or absolutely no) triazoles, benzotriazoles, substituted thiadiazoles, imidazoles, thiazoles, tetrazoles, hydroxyquinolines, oxazolines, imidazolines, thiophenes, indoles, indazoles, quinolines, benzoxazines, dithiols, oxazoles, oxatriazoles, pyridines, piperazines, triazines, derivatives thereof, combinations thereof, or all corrosion inhibitors.

[0406] Compositions according to the present disclosure may contain an additive having a different enumerated function that also has secondary effects as a corrosion inhibitor (for example, Component B Functionalized Polymer described above, may also have corrosion inhibitor effects). These additives are not included as corrosion inhibitor for purposes of determining the amount of corrosion inhibitor in a lubricating oil composition or concentrate herein.

K. Antiwear Agents

[0407] The lubricating oil composition of the present disclosure can contain one or more antiwear agents that can reduce friction and excessive wear. Any antiwear agent known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable antiwear agents include zinc dithiophosphate, metal (*e.g.*, Pb, Sb, Mo, and

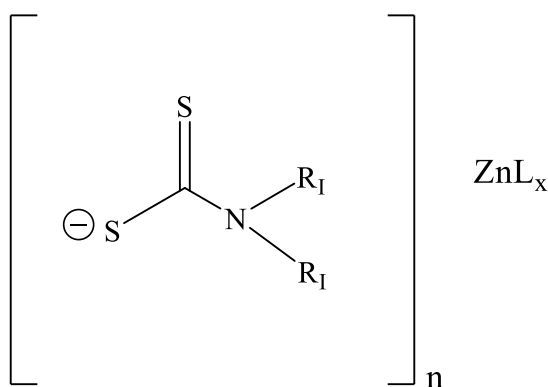
the like) salts of dithiophosphates, metal (*e.g.*, Zn, Pb, Sb, Mo, and the like) salts of dithiocarbamates, metal (*e.g.*, Zn, Pb, Sb, and the like) salts of fatty acids, boron compounds, phosphate esters, phosphite esters, amine salts of phosphoric acid esters or thiophosphoric acid esters, reaction products of dicyclopentadiene and thiophosphoric acids and combinations thereof. The amount of the antiwear 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.

[0408] In embodiments, the antiwear 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 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.

[0409] Useful antiwear agents also include substituted or unsubstituted thiophosphoric acids, and salts thereof include zinc-containing compounds such as zinc dithiophosphate compounds selected from zinc dialkyl-, diaryl- and/or alkylaryl-dithiophosphates.

[0410] A metal alkylthiophosphate and more particularly a metal dialkyl dithio phosphate in which the metal constituent is zinc, or zinc dialkyl dithio phosphate (ZDDP) can be a useful component of the lubricating compositions of this disclosure. ZDDP can be derived from primary alcohols, secondary alcohols or mixtures thereof. ZDDP compounds generally are of the formula $\text{Zn}[\text{SP}(\text{S})(\text{OR}_1)(\text{OR}_2)]_2$ where R_1 and R_2 are C_1 - C_{18} alkyl groups, preferably C_2 - C_{12} alkyl groups. These alkyl groups may be straight chain or branched. Alcohols used in the ZDDP can be 2-propanol, butanol, secondary butanol, pentanols, hexanols such as 4-methyl-2-pentanol, n-hexanol, n-octanol, 2-ethyl hexanol, alkylated phenols, and the like. Mixtures of secondary alcohols or of primary and secondary alcohol can be used. Alkyl aryl groups may also be used. Useful zinc dithiophosphates include secondary zinc dithiophosphates such as those available from The Lubrizol Corporation under the trade designations "LZ 677A", "LZ 1095" and "LZ 1371", from Chevron Oronite under the trade designation "OLOA 262" and from Afton Chemical under the trade designation "HiTEC™ 7169".

[0411] In embodiments, the zinc compound can be a zinc dithiocarbamate complex, such as the zinc dithiocarbamates represented by the formula:



where each R_I is independently a linear, cyclic, or branched, saturated or unsaturated, aliphatic hydrocarbon moiety having from 1 to about 10 carbon atoms, n is 0, 1, or 2, L is a ligand that saturates the coordination sphere of zinc, and x is 0, 1, 2, 3, or 4. In certain embodiments, the ligand, L , is selected from the group consisting of water, hydroxide, ammonia, amino, amido, alkylthiolate, halide, and combinations thereof.

[0412] The antiwear additives, such as ZDDP and/or the zinc carbamates, are typically used in amounts of from about 0.4 wt % to about 1.2 wt %, preferably from about 0.5 wt % to about 1.0 wt %, and more preferably from about 0.6 wt % to about 0.8 wt %, based on the total weight of the lubricating composition, although more or less can often be used advantageously. Preferably, the antiwear additive is ZDDP, preferably a secondary ZDDP, and is present in an amount of from about 0.6 to 1.0 wt % of the total weight of the lubricating composition.

[0413] Antiwear additives useful herein also include boron-containing compounds, such as borate esters, borated fatty amines, borated epoxides, alkali metal (or mixed alkali metal or alkaline earth metal) borates and borated overbased metal salts.

[0414] Compositions according to the present disclosure may contain an additive having a different enumerated function that also has secondary effects as an antiwear agent (for example, Component B Functionalized Polymer described above, may also have antiwear effects). These additives are not included as antiwear agents for purposes of determining the amount of antiwear agents in a lubricating oil composition or concentrate herein.

L. Demulsifiers

[0415] Demulsifiers useful herein include those described in US Patent No. 10,829,712 (col 20, ln 34-40). Typically, a small amount of a demulsifying component may be used herein. A preferred demulsifying component is described in European Patent No. 330 522. It is obtained by reacting an alkylene oxide with an adduct obtained by reacting a bis-epoxide with a polyhydric alcohol. Such additives may be used in an amount of about 0.001 to 5 wt %, preferably about 0.01 to 2 wt %.

M. Seal Compatibility Agents

[0416] Other optional additives include seal compatibility agents such as organic phosphates, aromatic esters, aromatic hydrocarbons, esters (butylbenzyl phthalate, for example), and polybutenyl succinic anhydride. Such additives may be used in an amount of about 0.001 to 5 wt %, preferably about 0.01 to 2 wt %. In embodiments the seal compatibility agents are sea swell agents, such as PIBSA (polyisobutenyl succinic anhydride).

N. Extreme Pressure Agents

[0417] The lubricating oil composition of the present disclosure can contain one or more extreme pressure agents that can prevent sliding metal surfaces from seizing under conditions of extreme pressure. Any extreme pressure agent known by a person of ordinary skill in the art may be used in the lubricating oil composition. Generally, the extreme pressure agent is a compound that can combine chemically with a metal to form a surface film that prevents the welding of asperities in opposing metal surfaces under high loads. Non-limiting examples of suitable extreme pressure agents include sulfurized animal or vegetable fats or oils, sulfurized animal or vegetable fatty acid esters, fully or partially esterified esters of trivalent or pentavalent acids of phosphorus, sulfurized olefins, dihydrocarbyl polysulfides, sulfurized Diels-Alder adducts, sulfurized dicyclopentadiene, sulfurized or co-sulfurized mixtures of fatty acid esters and monounsaturated olefins, co-sulfurized blends of fatty acid, fatty acid ester and alpha-olefin, functionally substituted dihydrocarbyl polysulfides, thia-aldehydes, thia-ketones, epithio compounds, sulfur-containing acetal derivatives, co-sulfurized blends of terpene and acyclic olefins, and poly sulfide olefin products, amine salts of phosphoric acid esters or thiophosphoric acid esters, and combinations thereof. The amount of the extreme pressure 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.

O. Non-basestock Unsaturated Hydrocarbons

[0418] The lubricating oil composition of the present disclosure can contain one or more unsaturated hydrocarbons. These unsaturated hydrocarbons are distinct from any baseoils (lubricating oil basestocks of Group I, II, III, IV and/or V) and/or viscosity modifiers that may be present in the compositions and always have at least one (and typically only one, in the case of linear alpha-olefins, or LAOs) unsaturation per molecule. Without being bound by theory, the unsaturation(s) may provide an antioxidation functionality and/or a sulfur-trapping functionality that may supplement and/or replace one or more antioxidant additives and/or one or more corrosion inhibitor additives, but unsaturated hydrocarbons (LAOs) will typically not

provide the only antioxidant nor the only corrosion inhibition functionality in lubrication oil compositions. Non-limiting examples of unsaturated hydrocarbons can include one or more unsaturated C₁₂-C₆₀ hydrocarbons (such as C₁₂-C₄₈ hydrocarbons, C₁₂-C₃₆ hydrocarbons, C₁₂-C₃₀ hydrocarbons, or C₁₂-C₂₄ hydrocarbons). When only one unsaturation is present, the unsaturated hydrocarbons may be termed linear alpha-olefins (LAOs). Other non-limiting examples of unsaturated hydrocarbons can include oligomers/polymers of polyisobutylenes that have retained (or been post-polymerization modified to exhibit) a (near-) terminal unsaturation, and/or blends thereof. When present, unsaturated hydrocarbons (LAOs) may be present from 0.01 to 5 wt % (in particular, 0.1 to 3 mass %, alternately 0.1 to 1.5 mass %), based on total weight of the lubricating oil composition.

[0419] When lubricating oil compositions contain one or more of the additives discussed above, the additive(s) are typically blended into the composition in an amount sufficient for it to perform its intended function. Typical amounts of such additives useful in the present disclosure, especially for use in crankcase lubricants, are shown in the Table below.

[0420] It is noted that many of the additives are shipped from the additive manufacturer as a concentrate, containing one or more additives together, with a certain amount of base oil or other diluents. Accordingly, the weight amounts in the table below, as well as other amounts mentioned herein, are directed to the amount of active ingredient (that is the non-diluent portion of the ingredient). The weight percent (mass %) indicated below is based on the total weight of the lubricating oil composition.

Typical Amounts of Optional Lubricating Oil Components

Additive Formulations	A (mass % a.i.)	B (mass % a.i.)	C (mass % a.i.)
Dispersant	0.1 - 20	0.1 - 20	1 - 8
Detergents	0.1 - 20	0.1 - 20	0.2 - 9
Corrosion Inhibitor Anti-rust / extreme pressure agents	0 - 7	0.05 - 5	0.1 - 1.5
Antioxidant	0.01 - 10	0.1 - 5	0.1 - 4
Pour Point Depressant		0 - 5	0.01 - 1.5
Anti-foaming Agent		0 - 5	0.001 - 0.15
Functionalized Polymer	0.01 - 10	0.1 - 5	0.1 - 2
Friction Modifier		1.	0.5
Antiwear Agent	0.01-10	0.1 - 5	0.1 - 3
Viscosity Modifier		0.01 - 10	0.25 - 3
Seal Swell Agents		0 - 5	0 - 2
Extreme Pressure Agents		0 - 5	0 - 3
Unsaturated Hydrocarbons (LAOs)		0 - 5	0 - 3

Basestock	Balance (such as 50 to 95 %)	Balance	Balance
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[0421] The foregoing additives are typically commercially available materials. These additives may be added independently, but are usually pre-combined in packages, which can be obtained from suppliers of lubricant oil additives. Additive packages with a variety of ingredients, proportions and characteristics are available and selection of the appropriate package will take the use of the ultimate composition into account.

Fuels

[0422] This disclosure also relates to a method of lubricating an automotive internal combustion engine during operation of the engine comprising:

- (i) providing to a crankcase of the automotive internal combustion engine an automotive crankcase the lubricating composition of described herein;
- (ii) providing a hydrocarbon fuel in the automotive internal combustion engine; and
- (iii) combusting the fuel in the automotive internal combustion engine, such as a spark-ignited or compression-ignited two- or four-stroke reciprocating engines such as a diesel engine or passenger car engine (such as a spark-ignited combustion engine).

[0423] This disclosure also relates to a fuel composition comprising the lubricating oil compositions described herein and a hydrocarbon fuel, wherein the fuel may be derived from petroleum and/or biological sources ("biofuel" or "renewable fuel"). In embodiments, the fuel comprises from 0.1 to 100 mass % renewable fuel, alternately from 1 to 75 mass % renewable fuel, alternately from 5 to 50 mass % renewable fuel, based upon the total mass of the from 1 to 50 mass % renewable fuel and the petroleum derived fuel.

[0424] The renewable fuel component is typically produced from vegetable oil (such as palm oil, rapeseed oil, soybean oil, jatropha oil), microbial oil (such as algae oil), animal fats (such as cooking oil, animal fat, and/or fish fat) and/or biogas. Renewable fuel refers to biofuel produced from biological resources formed through contemporary biological processes. In an embodiment, the renewable fuel component is produced by means of a hydrotreatment process. Hydrotreatment involves various reactions where molecular hydrogen reacts with other components, or the components undergo molecular conversions in the presence of molecular hydrogen and a solid catalyst. The reactions include, but are not limited to, hydrogenation, hydrodeoxygenation, hydrodesulfurization, hydrodenitrification, hydrodemetallization, hydrocracking, and isomerization. The renewable fuel component may have different distillation ranges, which provide the desired properties to the component, depending on the intended use.

Uses

[0425] The lubricating compositions of the disclosure may be used to lubricate mechanical engine components, particularly in internal combustion engines, *e.g.*, spark-ignited or compression-ignited, two- or four-stroke reciprocating engines, by adding the lubricant thereto. Typically, they are crankcase lubricants, such as passenger car motor oils or heavy-duty diesel engine lubricants.

[0426] In particular, the lubricating compositions of the present disclosure are suitably used in the lubrication of the crankcase of a compression-ignited, internal combustion engine, such as a heavy-duty diesel engine.

[0427] In particular, the lubricating compositions of the present disclosure are suitably used in the lubrication of the crankcase of a spark-ignited turbo charged internal combustion engine.

[0428] In embodiments, the lubricating oils of this disclosure are used in spark-assisted high compression internal combustion engines and, when used in high compression spark ignition internal combustion engines the lubricating oil compositions of this disclosure are useful in lubricating high compression spark ignition engines.

[0429] In embodiments, the lubricating compositions of the present disclosure are suitably used in the lubrication of the crankcase of an engine for a heavy-duty diesel vehicle (*i.e.*, a heavy-duty diesel vehicle having a gross vehicle weight rating of 10,000 pounds or more.)

[0430] In embodiments, the lubricating compositions of the present disclosure are suitably used in the lubrication of the crankcase of a passenger car diesel engine.

[0431] In particular, lubricating oil formulations of this disclosure are particularly useful in compression-ignited internal combustion engines, *i.e.*, heavy-duty diesel engines, employing low viscosity oils, such as API FA-4 and future oil categories, in which wear protection of the valve train becomes challenging.

[0432] This disclosure further relates to:

1. An amide, imide, and/or ester functionalized partially or fully saturated polymer comprising C₄₋₅ olefins having:
 - i) an Mw/Mn of less than 2,
 - ii) a Functionality Distribution (Fd) value of 3.5 or less, and
 - iii) an Mn of 10,000 g/mol or more (GPC-PS) of the polymer prior to functionalization, provided that, if the polymer prior to functionalization is a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 g/mol (GPC-PS).
2. The functionalized polymer of paragraph 1, wherein the functionalized polymer comprises at least about 50 % of 1,4-insertions of monomer.

3. The functionalized polymer of paragraph 1 or 2, wherein the polymer prior to functionalization has an Mn of 25,000 g/mol or more (GPC-PS).
4. The functionalized polymer of any of paragraphs 1 to 3, wherein the polymer prior to functionalization has an Mn of 30,000 g/mol or more (GPC-PS).
5. The functionalized polymer of any of paragraphs 1 to 4, wherein the polymer prior to functionalization comprises at least 90 mol % isoprene repeat units.
6. The functionalized polymer of any of paragraphs 1 to 5, wherein the polymer prior to functionalization is homo-polyisoprene.
7. The functionalized polymer of any of paragraphs 1 to 6, wherein the polymer is partially or fully hydrogenated prior to functionalization.
8. The functionalized polymer of paragraph 1, wherein the functionalized polymer comprises a partially or fully saturated homopolyisoprene having an Mn of 30,000 to 100,000 g/mol (GPC-PS), containing one or more pendant amine groups, and having at least about 50 % of 1,4-insertions prior to functionalization.
9. The functionalized polymer of paragraph 1, wherein, if the polymer prior to functionalization is a C₄ olefin polymer, then the C₄ olefin polymer has an Mn of 15,000 g/mol or more (GPC-PS), and if the polymer prior to functionalization is a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 35,000 Mn (GPC-PS).
10. The functionalized polymer of paragraph 1 or 2, wherein the polymer prior to functionalization comprises 90 mol % or more isoprene repeat units and has an Mn of 30,000 g/mol or more (GPC-PS).
11. The functionalized polymer of paragraph 1 or 2, wherein the polymer prior to functionalization is homopolyisoprene and has an Mn of 30,000 g/mol or more (GPC-PS).
12. The functionalized polymer of paragraph 1 or 2, wherein the polymer prior to functionalization is a partially or fully hydrogenated polymer of homopolyisoprene having an average functionality of 1 to 20 per 10,000 g/mol.
13. The functionalized polymer of any of paragraphs 1 to 12, wherein styrene repeat units are absent in the polymer.
14. The functionalized polymer of any of paragraphs 1 to 13, wherein butadiene repeat units are absent in the polymer.
15. The functionalized polymer of any of paragraphs 1 to 14, wherein the polymer is not homopolyisobutylene.
16. The functionalized polymer of any of paragraphs 1 to 15, wherein the polymer is not a copolymer of isoprene and butadiene.

17. The functionalized polymer of any of paragraphs 1 to 16, wherein the polymer has an average functionality of 1.4 to 20 FG grafts/polymer chain, as determined by GPC-PS.
18. The functionalized polymer of any of paragraphs 1 to 18, wherein the polymer is obtained by reacting fully or partially hydrogenated polymers of C₄₋₅ conjugated dienes having an Mw/Mn of less than 2 and an Mn of 10,000 g/mol or more, with an acylating agent and thereafter reacting the acylated polymer with an amine to form an imide, amide or combination thereof.
19. The functionalized polymer of paragraph 18, wherein side reactions are minimized, optionally, by adding the acylating agent in a continuous or semi-continuous fashion, and/or by introducing the fully or partially hydrogenated polymer into batch, semi-continuous, or continuous reactor operations as solution or suspension in diluent, said solution or suspension comprising 45 wt % or more of the fully or partially hydrogenated polymer, based upon the weight of the fully or partially hydrogenated polymer and diluent.
20. A lubricating oil composition comprising or resulting from the admixing of:
- (i) at least 50 mass % of one or more base oils, based upon the weight of the lubricating oil composition;
 - (ii) one or more dispersants;
 - (iii) one or more detergents; and
 - (iv) one or more functionalized polymers of any of paragraphs 1 to 19.
21. A lubricating oil composition of paragraph 20, where the lubricating oil composition preferably has:
- a) an SAE viscosity grade of 20W-X, 15W-X, 10W-X, 5W-X, or 0W-X, where X represents any one of 8, 12, 16, 20, 30, 40, and 50, and
 - b) soot induced wear of 55 mg or less (as determined by Cummins ISB test for valve train wear protection), and
 - c) soot-induced viscosity increase of 12 cSt or less at 6 % soot (as determined by Mack T11 Test for Soot-Induced Viscosity Control).
22. A lubricating oil composition of paragraph 20 or 21, comprising or resulting from the admixing of:
- (i) from 50 to 99 mass % of one or more base oils, based upon the weight of the lubricating oil composition;
 - (ii) from 0.01 to 20 wt % based on total weight of the lubricating oil composition, of one or more dispersants;

(iii) from 0.10 to 20 mass %, based upon the weight of the lubricating oil composition, of one or more detergents;

(iv) from 0.10 to 20 mass %, based upon the weight of the lubricating oil composition, of one or more functionalized polymers of any of paragraphs 1 to 19.

23. The lubricating oil composition of any of paragraphs 20 to 22, further comprising one, two, three, four, five, six, or more of additional additives selected from the group consisting of: friction modifiers; antioxidants; pour point depressants; anti-foam agents; viscosity modifiers; inhibitors and/or anti-rust agents; and antiwear agents.

24. The lubricating oil composition of any of paragraphs 20 to 23, further comprising one, two, three, four, five, six, or more of:

D) from 0.01 to 5 wt %, based on total weight of the lubricating oil composition, of one or more friction modifiers;

E) from 0.01 to 10 wt %, based on total weight of the lubricating oil composition, of one or more antioxidants;

F) from 0.01 to 5 wt %, based on total weight of the lubricating oil composition, of one or more pour point depressants;

G) from 0.001 to 5 wt %, based on total weight of the lubricating oil composition, of one or more anti-foam agents;

H) from 0.001 to 10 wt %, based on total weight of the lubricating oil composition, of one or more viscosity modifiers;

J) from 0.0 to 5 wt %, based on total weight of the lubricating oil composition, of one or more inhibitors and/or anti-rust agents; and/or

K) from 0.001 to 10 wt %, based on total weight of the lubricating oil composition, of one or more antiwear agents.

25. The lubricating oil composition of any of paragraphs 20 to 24, where the lubricating oil composition is absent phenolic antioxidant and/or styrenic polymer.

26. The lubricating oil composition of any of paragraphs 20 to 24, where the functionalized polymer is a partially or fully saturated homo-polyisoprene having an Mn of 30,000 to 100,000 g/mol (GPC-PS), containing one or more pendant amine groups, and having at least about 60 % of 1,4-insertions.

27. The lubricating oil composition of any of paragraphs 20 to 26, where the lubricating oil composition comprises less than 5 mass % based on total weight of the lubricating oil composition, of functionalized oil.

28. The lubricating oil composition of any of paragraphs 20 to 27, where the lubricating oil composition comprises less than 5 mass % based on total weight of the lubricating oil composition, of aliphatic or aromatic solvent.
29. The lubricating oil composition of any of paragraphs 20 to 28, where the lubricating oil composition has a total Saponification Number (SAP) of 25 mgKOH/g or more as determined by ASTM D94 and the functionalized polymer has a Functionality Distribution (Fd) value of 3.5 or less.
30. The lubricating oil composition of any of paragraphs 20 to 29, where the lubricating oil composition comprises less than 5 mass % based on total weight of the lubricating oil composition, of secondary hydrocarbyl amine compounds and tertiary hydrocarbyl amine compounds.
31. The lubricating oil composition of any of paragraphs 20 to 30, wherein the detergent comprises one or more oil-soluble neutral or overbased sulfonates, phenates, sulfurized phenates, thiophosphonates, salicylates, naphthenates and other oil-soluble carboxylates of an alkali or alkaline earth metal (such as sodium, potassium, lithium, calcium, and magnesium, such as Ca and/or Mg).
32. The lubricating oil composition of any of paragraphs 20 to 31, wherein the dispersant comprises one or more borated or unborated poly(alkenyl)succinimides, where the polyalkenyl is derived from polyisobutylene and the imide is derived from a polyamine.
33. The lubricating oil composition of any of paragraphs 20 to 32, wherein the dispersant comprises one or more, optionally borated, higher molecular weight (M_n 1600 g/mol or more, such as 1800 to 3000 g/mol) poly(alkenyl)succinimide and one or more, optionally borated, lower molecular weight (M_n less than 1600 g/mol) poly(alkenyl)succinimide.
34. The lubricating oil composition of paragraph 33, wherein the higher molecular weight poly(alkenyl)succinimide is present in the lubricating composition in an amount of 0.8 to 6 wt % and the lower molecular weight poly(alkenyl)succinimide is present in the lubricating composition in an amount of from 1.5 to 5 wt %.
35. The lubricating oil composition of any of paragraphs 20 to 34, wherein the lubricating oil composition is a heavy-duty diesel oil.
36. The lubricating oil composition of any of paragraphs 20 to 35, wherein the soot-induced viscosity increase at 6 % soot is 12 cSt or less as determined by ASTM D7156-19.
37. The lubricating oil composition of any of paragraphs 20 to 36, wherein the camshaft wear is less than 50 μm as determined by ASTM D7484-21.

38. A method of lubricating an internal combustion engine during operation of the engine comprising:

- (i) providing to a crankcase of the internal combustion engine the lubricating composition of any of paragraphs 20 to 35;
- (ii) providing a fuel in the internal combustion engine; and
- (iii) combusting the fuel in the automotive internal combustion engine.

39. The method of paragraph 38, wherein the fuel is one of more of hydrocarbon fuel, renewable fuel, hydrogen fuel or any blend thereof.

40. The method of paragraph 38, wherein the engine is a diesel engine.

41. A fuel composition comprising the composition of any of paragraphs 1 to 19 and one or more of hydrocarbon fuel, renewable fuel, hydrogen fuel, or any blend thereof.

42. A concentrate comprising or resulting from the admixing of from 1 to less than 50 mass % of one or more base oils; and from 0.10 to 20 mass %, based upon the weight of the concentrate, of one or more of the functionalized polymers of any of claims 1 to 19, based upon the weight of the concentrate.

43. An amide, imide, and/or ester functionalized partially or fully saturated homopolyisoprene polymer having: i) an Mw/Mn of less than 2, ii) a Functionality Distribution (Fd) value of 3.5 or less, and iii) an Mn of 10,000 to 300,000 g/mol (GPC-PS) of the polymer prior to functionalization.

[0433] The following non-limiting examples are provided to illustrate the disclosure.

Experimental

[0434] All molecular weights are number average molecular weights (Mn) reported in g/mol, as determined by gel permeation chromatography using polystyrene standards, unless otherwise noted. "A.I.", "a.i.", and "ai" are wt % active ingredient, unless otherwise indicated.

Testing Procedures

[0435] KV100 is Kinematic viscosity measured at 100° C according to ASTM D445-19a.

[0436] KV40 is Kinematic viscosity measured at 40° C according to ASTM D445-19a.

[0437] Sulfur content in oil is measured by ASTM D5185.

[0438] Sulfated ash ("SASH") content is measured by ASTM D874.

[0439] Phosphorus, Boron, Calcium, Zinc, Molybdenum, and Magnesium content are measured by ASTM D5185.

[0440] Nitrogen content in the LOC is measured by ASTM D5762.

[0441] Nitrogen in the functionalized polymer is measured by ASTM D5291.

[0442] The moments of molecular weight (M_w , M_n , M_z) were determined by Gel Permeation Chromatography ("GPC-PS") using polystyrene standards (Acquity™ APC Polystyrene High MW Calibration Kit, 266-1,760,000 Da) as follows.

[0443] Molecular weights [number average molecular weight (M_n), weight average molecular weight (M_w), and z-average molecular weight (M_z)] are determined using an Agilent Acquity P-SM-FTN and P-15m high temperature GPC-SEC (gel permeation/size exclusion chromatograph) equipped with an on-line differential refractive index (DRI) detector and a PDA UV detector for 215,254 and 304 wavelengths. The GPC uses 3 Agilent PLgel 10 micron Mixed B LS columns. The column separation is performed using a flow rate of 0.25mL/min and a nominal injection volume of 10 microliters. The detectors and columns are maintained at 30° C when in low flow mode(idle) and heated up to 35° C when preparing to run samples. The stream emerging from the SEC columns is directed into the optical flow cell and then into the DRI detector. Solvent for the SEC experiment is un-inhibited THF(tetrahydrofuran). Polymer solutions are prepared by placing dry polymer in a glass container, adding the desired amount of THF. Once the sample is added to machine it is given time to reach 35° C before the run begins. The GPC runs a pre-run programmed equilibrium of approx 1.5 hours. Samples are agitated for 2 to 15 hours depending on solubility. Samples are filtered after the agitation and before being run. All quantities are measured gravimetrically. The THF densities used to express the polymer concentration in mass/volume units are 0.887 g/mL at 68° C. The injection sample concentration is 3 mg/mL. Prior to running each sample, the DRI detector and the injector are purged. Flow rate in the apparatus is then increased from 0.01 to 0.25 mL/minute, and the DRI is allowed to stabilize for 4 to 5 hours before injecting the first sample. Software used to run the GPC and prepare reports is Empower™ 3, version 7.41.00.00.

[0444] "FG" means functional group.

[0445] Average functionality [also referred to as Average Functionality Value (F_v)] and Functionality Distribution (F_d) value are determined as follows.

[0446] A simplified non-polymeric material bearing the ADPA-imide functional group (ODSA-ADPA) was prepared according to the procedure below; and subsequently used as a reference material and calibrant for the functional group GPC analysis described further below.

[0447] 268 g of octadecenylsuccinic anhydride (mixture of isomers, 0.094 mol) was added to a four-necked, round-bottom flask, equipped with an air-powered stirrer, a thermocouple connected to temperature controller and electric heating mantle, and a nitrogen inlet. The

material was heated to 170° C with constant stirring and under a continuous nitrogen sweep through the reactor headspace.

[0448] 17.2 g of 4-aminodiphenylamine (ADPA, 0.094 mol) was added portionwise to the hot reaction mixture, allowing time for any foaming to subside as the amine addition continued. The mixture was heated until the reaction was determined to be complete by FTIR analysis of the anhydride and imide peaks at ca. 1780 and 1700 cm⁻¹, respectively (the anhydride peak was completely consumed, and the imide peak no longer increasing – approx. 2-3h). The material was allowed to partially cool (below 100° C) before being drained out of the reactor. It was used directly as the GPC calibrant without further purification.

[0449] A GPC calibration curve (shown as Figure 1) was prepared from ODSA-ADPA samples at 0.01, 0.02, 0.03, 0.04, and 0.05 mg/ml, according to the GPC procedure described above, and integrated in the UV 304 nm channel.

[0450] Samples of the functional polymer were prepared and submitted for GPC analysis as described above. The chromatogram was integrated by drawing a flat baseline across the base of each of the peaks, in line with the solvent baseline. When the chromatogram peaks were not resolved to the baseline (baseline indicated by triangle in Figure 2 abscissa), a vertical cut was made at the minimum point between them (shown as the diamond in Figure 2 abscissa). The minimum point is the inflection point in the GPC trace where the second derivative of the curve changes in sign (*e.g.*, from negative to positive or vice versa). For the purposes of the Average Functionality Value (Fv) and Functionality Distribution (Fd) calculations, any chain-coupled and chain-fragmented polymer resolved from the main polymer peak should be included in all calculations (Mn, Mw, PDI (Mw/Mn), and any subsequent calculations) as part of the main peak. A representative chromatogram for GPC analysis is shown as Figure 2.

[0451] The Average Functionality Value (Fv) of the sample is defined as the average number of functional groups per polymer chain across the entire sample and is calculated via Eq 1:

$$Fv = \frac{\text{moles}_{\text{amine FG}}}{\text{moles}_{\text{polymer}}} = \frac{(UV304 \text{ int}_{\text{total}})}{(FG \text{ cal slope})} * \frac{Mn}{(\text{poly mg/ml})} \quad (1)$$

where,

Fv = the average functionality in units of FG grafts/polymer chain calculated across the total sample,

UV304 int_{total} = the total polymer peak integration in the UV304 channel,

FG Cal Slope = the slope of the UV304 calibration curve from ODSA-ADPA,

Mn = the polymer peak number average molecular weight (using polystyrene standard), and

Poly mg/ml = the concentration of polymer (excluding functional groups) in the total sample in units of mg/ml, measured gravimetrically during sample preparation.

[0452] The Functionality Distribution (Fd) value represents the range of functionalities across the MW distribution in the sample (*i.e.*, the difference in functionality between high MW and low MW fractions in the sample). Fd is calculated via eq. 2:

$$Fd = PDI * \frac{F_{max} - F_{min}}{F_v} \quad (2)$$

where,

PDI = polydispersity index of the total polymer peak, calculated from Mn/Mw,

F_{max} = the maximum functionality value between the 10th and 90th cumulative percentile (by RI) of the polymer peak,

F_{min} = the minimum functionality value between the 10th and 90th cumulative percentile (by RI) of the polymer peak, and

F_v = Average Functionality Value for the entire sample.

[0453] To calculate the individual functionalities across the sample, a detailed GPC slice report (exported with equal time in each slice, approx. 0.003 minutes per slice) containing data for slice retention time, MW, slice area, and cumulative % was exported for the polymer peak in both the refractive index (RI) and UV304 channel chromatograms.

[0454] The exported data for both channels were aligned at the same retention time, then offset by 6.0 seconds based on the measured retention time difference between the RI and UV detectors (*i.e.*, the time it takes for the material to travel from one detector to the other – this was determined by the retention time (RT) difference for polystyrene (PS) peaks in the calibration curve).

[0455] To verify the exported slice data matches the original data sufficiently, the sum of peak slice areas should be within ± 5 % of the total integrated peak area for both the RI and UV304 channel polymer peaks.

[0456] The polymer concentration in each slice of the RI channel data was determined by equation 3: (the functional polymer dn/dc doesn't need to be known, but it is assumed assumption here that dn/dc doesn't change with MW.)

$$poly\ mol/L_{slice} = \frac{poly\ mg/ml * \frac{RI\ int_{slice}}{RI\ int_{total}}}{Mn_{slice}} \quad (3)$$

where,

Poly mol/L_{slice} = the concentration of polymer (excluding functional groups) in units of mol/L calculated to be in a single MW slice of the RI chromatogram,

Poly mg/ml = the concentration of polymer (excluding functional groups) in units of mg/ml in the total sample, measured gravimetrically during sample preparation,

RI int_{slice} = the integration area of an individual slice in the RI chromatogram,

RI int_{total} = the total polymer peak integration in the RI chromatogram, and

Mn_{slice} = the MW of the polymer peak slice in the RI chromatogram.

[0457] The amine concentration in each slice of the UV304 channel data was determined via equation 4:

$$\text{Amine FG mol/L}_{\text{slice}} = \frac{\text{UV304 int}_{\text{slice}}}{\text{FG cal slope}} \quad (4)$$

where,

Amine FG mo/L_{slice} = the concentration of amine functional groups in units of mol/L calculated to be in a single slice of the UV 304 chromatogram,

UV304 int_{slice} = the integration area of an individual slice in the UV304 chromatogram, and

FG Cal Slope = the slope of the UV304 calibration curve from ODSA-ADPA.

[0458] From the polymer and amine FG slice concentrations calculated above, the functionality of the individual chromatogram slices can be calculated according to equation 5:

$$F_{\text{slice}} = \frac{\text{amine FG mol/L}_{\text{slice}}}{\text{poly mol/L}_{\text{slice}}} \quad (5)$$

where,

F_{slice} = the functionality in units of FG grafts/polymer chain calculated for an individual slice of the RI/UV304 chromatograms,

Poly mol/L_{slice} = the concentration of polymer (excluding functional groups) in units of mol/L calculated to be in a single MW slice of the RI chromatogram, and

Amine FG mo/L_{slice} = the concentration of amine functional groups in units of mol/L calculated to be in a single slice of the UV 304 chromatogram.

[0459] The calculations are completed for each slice of the exported chromatograms. The maximum and minimum functionality values between the 10th and 90th cumulative percentile of the polymer peak are selected as F_{max} and F_{min}, respectively, and used to calculate F_d as described above.

[0460] Soot Level was determined via TGA (thermo-gravimetric analysis) according to ASTM D5967.

[0461] Mack T11 Test for Soot-Induced Viscosity Control, ASTM D7156-19 was conducted in a Mack E-TECH V-MAC III diesel engine with exhaust gas recirculation. Two, 30-minute oil flushes, followed by 252 hours at constant speed 1800 rpm. The fuel injection timing was adjusted to targets of soot level (TGA, ASTM D5967) at 96 hours, 192 hours, and

228 hours, specifically a TGA soot level of 2.75 % +/- 0.25 % at 96 h, 5.50 % +/- 0.35 % at 192 h, and 6.53 % +/- 0.44 % at 228 h. Oil samples were taken every 12 hours to measure the soot level (TGA, ASTM D5967) and the kinematic viscosity at 100° C. The performance of the oil was determined by comparing the soot level at which a specified viscosity increase (4 cSt, 12 cSt and 15 cSt) is observed.

[0462] Cummins ISB Engine Test. Valve train wear protection was determined according to the Cummins ISB engine test, ASTM D7484-21 in a 5.9L 6-cyl diesel engine equipped with exhaust gas recirculation. The Cummins ISB test is a two-stage test. Stage A, for 100 hours, the engine was operated with retarded fuel-injection timing to generate excess soot according to the ASTM Protocol. During Stage B, for 250 hours, the engine was operated at cyclic conditions according to the ASTM Protocol to induce valve-train wear. Oil performance was determined by assessing crosshead weight loss (mg) measured as detailed in Section 8.1.5 in ASTM D7484-21, tappet weight loss (mg) measured as detailed in section 8.1.6 in ASTM D7484-21, and camshaft wear (µm) averaged over the 12 lobes measured with a Mitutoyo Snap Gauge and Mitutoyo Digital Indicator as detailed in Section 8.1.7 in ASTM D7484-21.

[0463] Ford 6.7L Power Stroke Diesel Engine Test for soot induced wear and viscosity control was conducted in a 6.7L Power Stroke Diesel engine. The test has two phases with the first phase of 10 hours at 2600 rpm/WOT followed by the second phase of 200 hours with the peak power 2800 rpm/WOT. In the second phase samples were taken every 25 hours for soot measurement according to ASTM D5967, TGA. Soot level is typically in the range between 5 to 7 % at the end of the test. After the test is completed the rocker arms are disassembled and weighed and compared to the weights before the tests to determine the weight loss. KV100 of the oil sample is also measured every 25 hours to determine the viscosity of the oil.

[0464] Caterpillar 1N Test for Piston Deposits was performed according to ASTM D6750-19. Oil consumption was also measured. The test was conducted in a single cylinder Caterpillar 1Y540 diesel engine (The engine was run under conditions detailed in Table A14.1 in ASTM D6750-19 for a 60-minute break-in period followed by 252 hours of test conditions. The piston was then removed and rated according to the procedures outlined in ASTM Deposit Rating Manual 20. Note that ASTM D6750 covers both the 1K procedure with 0.4% Fuel Sulfur and the 1N procedure with 0.04% Fuel Sulfur.

[0465] High Temperature High Shear Viscosity, ("HTHS" or "HTHS150") is determined at 150° C according to ASTM D4683 and is reported in cPs.

[0466] Cold Cranking Simulator ("CCS"), at -25° C unless otherwise indicated, is a measure of the cold-cranking characteristics of crankcase lubricants and is determined as described in ASTM D5293-92.

Materials

[0467] H-Polyisoprene-A - Hydrogenated isoprene polymer is an isoprene homopolymer having an Mn (GPC-polystyrene standard) of 40,000 g/mol, having greater than 90 % 1,4 insertions and about 99 % hydrogenation.

[0468] SA-H-Polyisoprene-A - Succinic anhydride modified hydrogenated isoprene polymer, also referred to as maleated hydrogenated isoprene polymer A, is prepared using H-Polyisoprene-A by adding 8.0 g of maleic anhydride to 1000 g of a 40 % solution of H-Polyisoprene-A in Group III oil (Yubase™ 4), under a nitrogen atmosphere at 170° C, and mixing until thoroughly combined. Then 8.0 g of a solution of 20 % t-butyl peroxide in 4 cSt Group III oil (Yubase™ 4) are added dropwise over 12 minutes. The reaction is then allowed to heat soak for 15 minutes. This process is repeated until a desired succinate functionality is obtained as determined by SAP (ASTM D94), after which the unreacted maleic anhydride is removed via nitrogen sparge.

[0469] 7.15-F-H-Polyisoprene-A Amine functionalized hydrogenated isoprene polymer having an average functionality (Fv) of 7.15 was prepared using SA-H-Polyisoprene-A (succinate functionality of 7.15) by adding one equivalent of amine (4-amino-diphenylamine, ADPA) per succinate unit (as determined by SAP, ASTM D94) at 170° C under nitrogen. The reaction is allowed to continue and heat soak for up to two hours, after which it is allowed to cool to ambient temperature. During cooling the material is combined with ethoxylated alcohol (such as Berol™ 1214 or Surfonic™ L24-4, Huntsman) at 10 wt % of reaction mixture. The 7.15-F-H-Polyisoprene-A had a Functionality Distribution (Fd) value of 1.76, an Mw/Mn of 1.239, an Mn of 31629 g/mol, an Mz of 47835 g/mol, and was used as a blend in oil with an ai of 0.5 wt %, unless otherwise indicated.

[0470] 4.0-F-H-Polyisoprene-A Amine functionalized hydrogenated isoprene polymer having an average functionality (Fv) of 4.01 was prepared using the same procedure used to make 7.15-F-H-Polyisoprene-A, except that the SA-H-Polyisoprene-A had a succinate functionality of 4.0. The 4.0-F-H-Polyisoprene-A had a Functionality Distribution (Fd) value of 1.85, an Mw/Mn of 1.191, an Mn of 35,061 g/mol, an Mz of 49,650 g/mol, and was used as a blend in oil with an ai of 0.5 wt %, unless otherwise indicated.

[0471] 3.6-F-H-Polyisoprene-A Amine functionalized hydrogenated isoprene polymer having an average functionality (Fv) of 3.61 was prepared using the same procedure used to

make 7.15-F-H-Polyisoprene-A, except that the SA-H-Polyisoprene-A had a succinate functionality of 3.6. The 3.6-F-H-Polyisoprene-A had a Functionality Distribution (Fd) value of 1.35, an Mw/Mn of 1.158, an Mn of 35,494 g/mol, an Mz of 47,336 g/mol, and was used as a blend in oil with an ai of 0.5 wt %, unless otherwise indicated.

[0472] 7.0-F-H-Polyisoprene-A Amine functionalized hydrogenated isoprene polymer having an average functionality (Fv) of 7.0 was prepared using the same procedure used to make 7.15-F-H-Polyisoprene-A, except that the SA-H-Polyisoprene-A had a succinate functionality of 7.0 and was diluted with additional oil (Group III, 4 cSt (Yubase™ 4) at the end of the reaction, prior to draining the reactants. The 7.0-F-H-Polyisoprene-A had a Functionality Distribution (Fd) value of 1.86, an Mw/Mn of 1.250, an Mn of 35,140 g/mol, an Mz of 55,726 g/mol, and was used as a blend in oil with an ai of 0.55 wt %, unless otherwise indicated.

[0473] F-EP-Copolymer is a functionalized ethylene-propylene copolymer prepared by maleating ethylene-propylene copolymer (Trilene™ CP-80, Lion Elastomers, Mn approx 23,000 g/mol, E/P approx 41/59) then reacting with amine N-phenyl-p-phenylenediamine (ADPA) using the same method as above to obtain an ethylene-propylene copolymer containing one or more pendant amine groups, having an average functionality (Fv) of 1.84, a Functionality Distribution (Fd) value of 6.89, an Mw/Mn of 1.837, an Mn of 18,529 g/mol, and an Mz of 56,721 g/mol, and was used as a blend in oil with an ai of 0.83 wt %, unless otherwise indicated.

Component Chart

Additional Lubricating Oil Components	Description
Borated PIBSA-PAM	Polyisobutylene succinimide having 1 to 3 mass % boron, based upon a PIB having an Mn of about 900-1050 g/mol in oil, ai ~40-50
PIBSA-PAM (2000+ Mn PIB)	Polyisobutylene succinimide based upon a PIB having an Mn of about 2000-2300 g/mol in oil, ai ~45-60
PIBSA-PAM (600+ Mn PIB)	Polyisobutylene succinimide based upon a PIB having an Mn of about 600-800 g/mol in oil, ai ~50-60
PIBSA-ester Dispersant	PIBSA ester of hydrocarbyl-bridged naphthyloxy alcohol in oil diluted to ~40 % ai. See US Patent No. 7,485,603.
PIBSA-PAM (900+ Mn)	Polyisobutylene succinimide based upon a PIB having an Mn of about 900-1050 g/mol in oil, ai ~45-55
Calcium sulfonate-300 TBN	Calcium sulfonate detergent having a TBN of approximately 300 mgKOH/g (on an as diluted basis) in oil, ai ~55
Calcium sulfonate-16 TBN	Calcium sulfonate detergent having a TBN of approximately 16 mgKOH/g (on an as diluted basis) in ~43 wt % oil
Magnesium sulfonate-400 TBN	magnesium sulfonate detergent having a TBN of approximately 400 mgKOH/g (on an as diluted basis) in oil, ai ~57
Calcium salicylate-64 TBN	Calcium salicylate detergent having a TBN of approximately 64 mgKOH/g (on an as diluted basis) in ~60 wt % oil

Calcium salicylate-350 TBN	Calcium salicylate detergent having a TBN of approximately 350 mgKOH/g (on an as diluted basis) in ~40 wt% oil
Mg sulfonate/Mg salicylate	Combination of Mg sulfonate and Mg salicylate detergents and having a TBN of approximately 310 mg KOH/g (on an as diluted basis) in ~40 wt % oil
Calcium phenate-45 TBN	Calcium phenate detergent having a TBN of approximately 45 mg KOH/g (on an as diluted basis) in oil, ai ~46
ZDDP	Zinc dialkyl dithiophosphate in oil, where the alkyl groups are derived from a mixture of 1° and 2° alcohols, ~75 ai
Mo Friction modifier	Trimeric Mo dialkyldithiocarbamate compound in oil, ~45 ai
DPA antioxidant	Alkylated diphenylamine antioxidant
Phenol antioxidant	Hindered phenol antioxidant
Sulfurized FAME	Sulfurized Fatty Acid Methyl Ester, derived from Lard Oil and/or Palm Oil
PIBSA-2000+ Mn	Polyisobutylene succinate having an Mn of approximately 2000-2300 g/mol in oil, ai ~70-75
Polyisobutylene- 900+	Polyisobutylene having an Mn of approximately 900-1050 g/mol
LAO	Blend of C ₁₂₋₂₄ linear alpha-olefins
Anti-foamant	Polydimethylsiloxane
Corrosion/rust inhibitor	nonionic fatty alcohol ethoxylate surfactant
Lube oil flow improver	Fumarate-Vinyl Acetate copolymer in oil
EP copolymer-viscosity modifier	Ethylene-propylene copolymer viscosity modifier in oil (shear stability index ~25)
SD-Star block copolymer viscosity modifier (Gp II)	Hydrogenated styrene -diene star block copolymer viscosity modifier in Group II diluent oil
SD-star-block copolymer viscosity modifier (Gp I)	Hydrogenated styrene-diene star copolymer viscosity modifier in Group I diluent oil

Examples

Example 1: Cummins ISB for Valve Train Wear Protection Test.

[0474] Oil A, Oil B, and Comparative Oil C were prepared and tested for valve train wear protection according to the Cummins ISB engine test described above. The data are reported in Table 1.

TABLE 1

Component/Property	Oil A mass %	Oil B mass %	Comparative Oil C mass %
Borated PIBSA-PAM	0.350	0.350	0.350
PIBSA-PAM (2000+ Mn PIB)	4.000	4.000	4.000
Calcium sulfonate-300 TBN-	1.220	1.220	1.220
Mg sulfonate/Mg salicylate	0.700	0.700	0.700
Calcium phenate-45 TBN	0.090	0.090	0.090
ZDDP	0.980	0.980	0.980
Mo Friction modifier	0.045	0.045	0.045
DPA antioxidant	0.550	0.550	0.550
Phenol antioxidant	1.400	1.400	1.400
PIBSA 2000+ Mn	0.200	0.200	0.200

Anti-foamant	0.005	0.005	0.005
Diluent oil (Group I)	2.110	2.110	2.110
Lube oil flow improver	0.300	0.300	0.300
EP copolymer viscosity modifier	4.200	4.200	4.200
H-Polyisoprene-A	---	---	1.200
3.6-F-H-Polyisoprene-A	1.440	---	---
7.15-F-H-Polyisoprene-A	---	1.61	---
Group II base oil KV ₁₀₀ 4 cSt	62.410	62.240	62.650
Group II base oil KV ₁₀₀ 6 cSt	20.000	20.000	20.000
SAE Viscosity Grade	10W-30	10W-30	10W-30
Mass % SASH	0.85	0.85	0.85
Mass % P	0.08	0.08	0.08
Mass % Ca	0.15	0.15	0.15
Mass % Mg	0.06	0.06	0.06
Mass % S	0.21	0.21	0.21
Camshaft Wear (µm) Cummins ISB engine test	54	71	106
Tappet Weight Loss (mg) Cummins ISB engine test	102	83	112
Crosshead Weight Loss (mg) Cummins ISB engine test	4.9	5.2	5.7

[0475] Comparative Oil C is the same formulation as Oil A except that the H-Polyisoprene-A component is not maleated or functionalized by reaction with amine/alcohol, that is, it is a hydrogenated polyisoprene polymer with no succinic anhydride or polyamine. Oil A and Oil B demonstrate a distinct and surprising improvement over comparative Oil C in the Cummins ISB valve train wear test in all the wear measurements, particularly in the parameter for camshaft wear.

Example 2: Mack T11 Test for Soot-Induced Viscosity Control

[0476] Oil D and Comparative Oil E were prepared and tested for soot-induced viscosity control according to the Mack T-11 engine test described above. An oil with better soot dispersancy would be able to hold a higher level of soot at the specified viscosity increase. Comparative Oil E is the same formulation as Oil D except that the functionalized polymer is an ethylene-propylene-succinic anhydride-polyamine copolymer (F-EP-Copolymer). The level of the functionalized polymers in Oil D and Comparative Oil E is adjusted so that they have equivalent % nitrogen contributed from the polyamine functional groups. At all three specified viscosity increase levels (4 cSt, 12 cSt and 15 cSt), Oil D can hold more soot, indicating it has surprisingly better soot dispersancy.

TABLE 2

Component/Property	Oil D mass %	Comparative Oil E mass %
7.0-F-H-Polyisoprene-A	1.382	0.000
F-EP-Copolymer	0.000	2.382
Borated PIBSA-PAM	0.968	0.968
PIBSA-PAM (2000+ Mn PIB)	5.797	5.797
Calcium salicylate-350 TBN	0.323	0.323
Magnesium sulfonate-400 TBN	0.968	0.968
Calcium salicylate-64 TBN	1.622	1.622
ZDDP	0.719	0.719
Mo friction modifier	0.098	0.098
DPA antioxidant	1.933	1.933
Sulfurized FAME	0.595	0.595
LAO	0.580	0.580
PIBSA 2000+Mn	0.194	0.194
Anti-foamant	0.002	0.002
Diluent oil (Group I)	0.959	0.959
Lube oil flow improver	0.200	0.200
SD-Star block copolymer viscosity modifier (Gp II)	0.000	6.500
SD-Star block copolymer viscosity modifier (Gp I)	6.500	0.000
Group II base stock 4 cSt	39.160	40.160
Group II base stock 6 cSt	38.000	36.000
KV ₁₀₀ (cSt)	14.90	14.90
HTHS150 (cP)	3.89	3.98
CCS @-25° C	6805	6102
% N from 7.0-F-H-Polyisoprene-A/F-EP-Copolymer (calculated)	0.011	0.010
SAE Viscosity Grade	10W-40	10W-40
Mass % SASH	0.712	0.712
Mass % P	0.058	0.058
Mass % Ca	0.078	0.078
Mass % Mg	0.088	0.088
Mass % S	0.265	0.226
Soot at 4 cSt Viscosity Increase (%)	4.2	3.6
Soot at 12 cSt Viscosity Increase (%)	5.1	3.7
Soot at 15 cSt Viscosity Increase (%)	5.7	4.3

Example 3: Mack T11 Test for Soot-Induced Viscosity Control

[0477] Oil T and Oil U were prepared and tested for soot induced viscosity control according to the Mack T11 Test described above. The data are reported in Table 3. Note that Oil U shows much better viscosity control than Oil T.

TABLE 3

Component/Property	Oil T mass %	Oil U mass %
Borated PIBSA-PAM	1.919	1.919
PIBSA-PAM (2000+ Mn PIB)	4.501	4.501
PIBSA-ester	1.249	1.249
Calcium sulfonate-300 TBN	0.850	0.850
Magnesium sulfonate/Mg salicylate	1.000	1.000
Calcium sulfonate-16 TBN	0.700	0.700
ZDDP	1.000	1.000
Mo friction modifier	0.180	0.180
DPA antioxidant	1.600	1.600
Phenol antioxidant	---	---
PIBSA 2000+ Mn	0.451	0.451
Anti-foamant	0.007	0.007
Diluent oil (Group I)	2.040	2.040
Lube oil flow improver	0.200	0.200
EP copolymer viscosity modifier	5.210	5.210
Polyisobutylene - 900+	0.599	0.599
7.0-F-H-Polyisoprene-A	---	1.563
4.0-F-H-Polyisoprene-A	1.473	---
Sulfurized FAME	0.700	0.700
Group II base oil KV ₁₀₀ 4 cSt	10.200	---
Group II base oil KV ₁₀₀ 6 cSt	66.120	---
EHC 45 Group II+ base stock 115 VI	---	10.200
EHC 65 Group II base stock 105 VI	---	66.030
SAE Viscosity Grade	15W-40	15W-40
Mass % SASH	0.85	0.85
Mass % P	0.08	0.08
Mass % Ca	0.11	0.11
Mass % Mg	0.08	0.08
Mass % S	0.32	0.32
Mg/Ca ratio	0.69	0.69
Mo, ppm	99	99
T-11 results		
Soot at 4cSt Viscosity Increase (%)	4.2	5.0
Soot at 12cSt Viscosity Increase (%)	4.7	6.9
Soot at 15cSt Viscosity Increase (%)	5.3	>7.4

Example 4: Mack T11 Test for Soot-Induced Viscosity Control

[0478] Oil P and Oil Q were prepared and tested for soot induced viscosity control according to the Mack T11 Test described above. The data are reported in Table 3. Note that Oil P shows much better viscosity control than Oil Q.

TABLE 4

Description	Oil P	Oil Q
Lube oil flow improver	0.200	0.200
7.0-F-H-Polyisoprene-A	1.560	1.000 (0.3 ai)
Borated PIBSA-PAM	0.500	0.500
PIBSA-PAM (2000+ Mn PIB)	4.000	4.000
PIBSA-ester Dispersant	0.500	0.500
PIBSA-PAM (600+ Mn PIB)	4.000	4.000
Ca sulfonate-300 TBN	0.600	0.600
Mg sulfonate-400 TBN	0.850	0.850
Ca phenate-45 TBN	0.800	0.800
ZDDP	1.000	1.000
Mo friction modifier	0.120	0.120
DPA antioxidant	2.000	2.000
Sulfurized FAME	0.800	0.800
PIBSA 2000+ Mn	0.000	0.000
PDMS Anti-foamant	0.008	0.008
Polyisobutylene Mn 900+	0.600	0.600
Group I diluent	2.062	2.062
EP copolymer viscosity modifier	5.500	6.000
Group II base oil KV ₁₀₀ 4 cSt	14.000	10.240
Group II base oil KV ₁₀₀ 6 cSt	60.900	64.720
SAE Viscosity Grade	15W-40	15W-40
Parameters		
Mass % SASH	0.84	0.84
Mass % S	0.33	0.33
Mass % P	0.08	0.08
Mass % Ca	0.11	0.11
Mass % Mg	0.08	0.08
Mg/Ca ratio	0.69	0.69
Mo, ppm	66	66
T-11 Results		
Soot at 4cSt Viscosity Increase (%)	4.4	4.0
Soot at 12cSt Viscosity Increase (%)	5.9	4.7
Soot at 15cSt Viscosity Increase (%)	6.6	5.2

Example 5: Ford 6.7L Power Stroke Diesel Engine Test for soot induced wear and viscosity control

[0479] Oil R and Oil S were prepared and tested for soot induced wear and viscosity control in the Ford diesel engine test described above. Oil R is a fully formulated oil with a viscosity grade of SAE 10W-30. Oil R contains an additive package at a treat rate of 19.2 %. Oil S contains the same additive package as Oil R, but with additional 0.5 % functionalized hydrogenated polyisoprene (7.0-F-H-Polyisoprene-A). Oil S show less weight loss and better viscosity control compared to Oil R.

[0480] Similarly, Oil V and Oil W were prepared and tested for soot induced wear and viscosity control in the Ford diesel engine test described above. Oil V is a fully formulated oil with a viscosity grade of SAE 10W-30. Oil V contains an additive package at a treat rate of 14.55 %. Oil W contains the same additive package as Oil V, but with additional 0.5 % functionalized hydrogenated polyisoprene (7.0-F-H-Polyisoprene-A). Oil W shows less weight loss and better viscosity control compared to Oil V.

TABLE 5

Description	Oil R	Oil S	Oil V	Oil W
Fumarate-Vinyl Acetate copolymer lube oil flow improver	0.200	0.200	0.15	0.15
7.0-F-H-Polyisoprene-A		1.560		1.560
PIBSA-PAM (2000+ Mn PIB)	4.000	4.000	6.12	6.12
PIBSA-ester dispersant	1.750	1.750	0.75	0.75
PIBSA-PAM (600+ Mn PIB)	4.000	4.000	---	---
Ca sulfonate-300 TBN	0.600	0.600	0.90	0.90
Mg sulfonate-400 TBN	0.850	0.850	1.10	1.10
Ca phenate-45 TBN	0.800	0.800	---	---
ZDDP	1.000	1.000	1.44	1.44
DPA antioxidant	2.500	2.500	0.50	0.50
Sulfurized FAME	0.800	0.800		
Phenol antioxidant			1.60	1.60
Mo friction modifier	---	---	0.12	0.12
PIBSA 2000+ Mn	---	---	0.30	0.30
Anti-foamant	0.008	0.008	0.002	0.002
Polyisobutylene Mn 900+	0.600	0.600		
Group I diluent	2.052	2.052	1.568	1.568
EP copolymer viscosity modifier	3.200	0.450	5.70	3.50
EHC 45 Group II+ base stock 115 VI	41.940	44.830	42.45	43.39
EHC 65 Group II base stock 105 VI	35.700	34.000	37.30	37.00
SAE Grade	10W-30	10W-30	10W-30	10W-30
Mass % SASH	0.85	0.85	1.00	1.00
Mass % S	0.31	0.31	0.29	0.29
Mass % P	0.08	0.08	0.12	0.12
Mass % Ca	0.11	0.11	0.11	0.11
Mass % Mg	0.08	0.08	0.10	0.10
Mg/Ca ratio	0.69	0.69	0.95	0.95
Ford Results				
Average rocker arm weight loss (mg)	76*	29	141**	61
KV100 increase at the end of the test (%)	960*	84	1120**	67

* average of two tests, ** average of three tests

Example 6: Caterpillar 1N for Piston Deposits Test

[0481] Oil F and Oil G were prepared and tested for tendency to form piston and ring groove deposits in the Caterpillar 1N engine test according to ASTM D6750, described above using the 1N procedure with 0.04% Fuel Sulfur. Oil F is a fully formulated 15W-40 lubricating oil containing 0.5 % of 7.0-F-H-Polyisoprene-A and an additive package (treat rate of 20 %,) with the remainder of the oil comprising Group II lubricating oil basestock and of a viscosity modifier. Oil G is the same formulation as Oil F except that it does not contain 7.0-F-H-Polyisoprene-A. The 7.0-F-H-Polyisoprene-A was replaced with the same Group II base stock in the bulk of the lubricating oil.

[0482] The piston ratings at the end of each test are given in the table below. WDN stands for Weighted Demerits in the Cat 1N; higher numbers indicate more severe deposits. Oil F, containing the 7.0 F-H-Polyisoprene-A at initial processing conditions, performs worse than Oil G, which has less discoloration caused by side products.

TABLE 6

Constituent	Oil F	Oil G
Borated PIBSA-PAM	0.500	0.500
PIBSA-PAM (2000+ Mn PIB)	4.000	4.000
PIBSA-ester Dispersant	1.750	1.750
PIBSA-PAM (600+ Mn PIB)	4.000	4.000
Calcium sulfonate-300 TBN	0.600	0.600
Calcium phenate -45 TBN	0.800	0.800
Magnesium sulfonate-400 TBN	0.850	0.850
ZDDP	1.000	1.000
Mo friction modifier	0.120	0.120
DPA antioxidant	2.500	2.500
Sulfurized FAME	0.800	0.800
Anti-foamant	0.008	0.008
Polyisobutylene-900+	0.600	0.600
Group I diluent oil	2.012	2.012
Lube Oil Flow Improver	0.200	0.200
EP copolymer viscosity modifier	4.500	4.500
7.0-F-H-Polyisoprene-A	1.560	---
EHC 65 Group II base stock 105 VI	74.200	75.760
Viscosity Grade	15W-40	15W-40
% SASH	0.837	0.837
% P	0.08	0.08
% Ca	0.113	0.113
% Mg	0.078	0.078
% S	0.331	0.328
Weighted Demerits number (WDN)	545	237

Top Groove Fill (%)	28	23
Top Land Heavy Carbon (%)	0	0

Example 7: Caterpillar 1N for Piston Deposits

[0483] Oil H, Oil I, and Oil J were prepared and tested for tendency to form piston and ring groove deposits in the Caterpillar 1N engine test, as described above. Oil H is a fully formulated 15W-40 lubricating oil containing an additive package at 20 % treat rate where the additive package contains 1.560 of wt % of 7.0-F-H-Polyisoprene-A.

[0484] Oil I is the same formulation as Oil H except that the functionalized polymer of hydrogenated-polyisoprene-succinic anhydride-polyamine 7.0-F-H-Polyisoprene-A was prepared differently. In Oil I, the 7.0-F-H-Polyisoprene-A was prepared according to the same process as the 7.0-F-H-Polyisoprene-A in Oil H except that, to minimize side products, the same amount of maleic anhydride was provided in a semi-continuous fashion (dripped in at 20 portions as opposed to 5 portions) over same period of time.

[0485] Oil J is the same formulation as Oil H except that the functionalized polymer of hydrogenated-polyisoprene-succinic anhydride-polyamine (7.0-F-H-Polyisoprene-A) was prepared differently. The 7.0-F-H-Polyisoprene-A in Oil J was prepared according to the same process as the 7.0-F-H-Polyisoprene-A in Oil I except that, to minimize side products, the starting H-Polyisoprene-A polymer backbone was delivered at a higher concentration in base oil (60 % instead of 40 %) and the same amount of maleic anhydride was provided in a semi-continuous fashion (dripped in at 60 portions as opposed to 5 portions) over same period of time.

[0486] The piston ratings at the end of each test are given in the table below. Higher Weighted Demerits numbers (WDN) in the Cat 1N test results indicate more severe deposits. Oil I and Oil J, appear to contain less maleated species (other than the intermediate maleated hydrogenated polyisoprene of the 7.0-F-H-Polyisoprene-A) due to the synthesis processes that were optimized to minimize side products, had significantly lower WDN than Oil H.

TABLE 7

Constituent	Oil H	Oil I	Oil J
PIBSA-PAM (900+ Mn)	4.000	4.000	4.000
Borated PIBSA-PAM	0.500	0.500	0.500
PIBSA-PAM (2000+ Mn PIB)	4.000	4.000	4.000
PIBSA-ester Dispersant	1.750	1.750	1.750
Calcium sulfonate-300 TBN	0.600	0.600	0.600
Calcium phenate-45 TBN	0.800	0.800	0.800
Magnesium sulfonate-400 TBN	0.850	0.850	0.850
ZDDP	1.000	1.000	1.000

Mo friction modifier	0.120	0.120	0.120
DPA antioxidant	2.500	2.500	2.500
Sulfurized FAME	0.800	0.800	0.800
Anti-foamant	0.008	0.008	0.008
Polyisobutylene-900+	0.600	0.600	0.600
Group I diluent oil	2.012	2.012	2.012
Lube Oil Flow Improver	0.200	0.200	0.200
EP copolymer viscosity modifier	4.500	4.500	4.500
7.0-F-H-Polyisoprene-A	1.560	---	---
7.0-F-H-Polyisoprene-A prepared with semicontinuous maleic anhydride addition in 20 portions	---	1.560	---
7.0-F-H-Polyisoprene-A prepared using a higher concentration of H-Polyisoprene-A and prepared in 60 portions	---	---	1.560
EHC 45 Group II+ base stock 115 VI	10.000	10.000	10.000
EHC 65 Group II base stock 105 VI	64.200	64.200	64.200
Viscosity Grade	15W-40	15W-40	15W-40
Mass % SASH	0.837	0.837	0.837
Mass % P	0.08	0.08	0.08
Mass % Ca	0.113	0.113	0.113
Mass % Mg	0.078	0.078	0.078
Mass % S	0.337	0.334	0.334
Weighted Demerits numbers	514	344	274
Top Groove Fill (%)	17	14	16
Top Land Heavy Carbon (%)	0	3	0

Example 8

[0487] Oils K, L, M, and N will be prepared as indicated below.

TABLE 8

Constituent	Oil K	Oil L	Oil M	Oil N
PIBSA-PAM (900+ Mn)	4.000	4.000	4.000	4.000
Borated PIBSA-PAM	0.500	0.500	0.500	0.500
PIBSA-PAM (2000+ Mn PIB)	4.000	4.000	4.000	4.000
7.0-F-H-Polyisoprene-A	1.560	1.650 (0.53 ai)	1.650 (0.53 ai)	1.750 (0.56 ai)
Calcium sulfonate-300 TBN	0.600	0.600	1.000	1.000
Magnesium sulfonate-400 TBN	0.850	0.850	0.850	0.850
Calcium phenate-45 TBN	0.800	0.800	---	---
ZDDP	1.000	1.000	1.000	1.000
Mo friction modifier	0.120	---	0.120	---
DPA antioxidant	1.600	1.900	1.900	2.100
Sulfurized FAME	0.560	0.640	0.560	0.700
PIBSA 2000+ Mn	0.300	0.300	0.300	0.300
Polyisobutylene Mn900+	0.600	0.600	0.600	0.600

Anti-foamant	0.008	0.008	0.008	0.008
Corrosion/rust inhibitor	---	---	0.100	0.100
Group I diluent oil	3.102	3.102	3.102	3.102
Treat rate wt %	19.600	19.950	19.690	20.010
Predicted Properties				
Mass % SASH	0.84	0.84	0.85	0.85
Mass % S	0.34	0.34	0.33	0.34
Mass % P	0.08	0.08	0.08	0.08
Mass % Ca	0.11	0.11	0.12	0.12
Mass % Mg	0.08	0.08	0.08	0.08
Mg/Ca ratio	0.69	0.69	0.67	0.67
Mo, ppm	66	0	66	0

Example 9

[0488] Oils O, P, Q and R will be prepared as indicated below.

TABLE 9

Constituent	Oil O	Oil P	Oil Q	Oil R
PIBSA-PAM (900+ Mn)	4.000	4.000	2.000	2.000
Borated PIBSA-PAM	0.500	0.500	0.500	0.500
PIBSA-PAM (2000+ Mn PIB)	4.000	4.000	6.000	6.000
7.0-F-H-Polyisoprene-A	2.300 (0.64 a.i.)	2.300 (0.64 a.i.)	2.150 (0.60 a.i.)	2.150 (0.60 a.i.)
Calcium sulfonate-300 TBN	1.025	1.025	1.000	1.000
Magnesium sulfonate-400 TBN	0.850	0.850	0.850	0.850
ZDDP	1.000	1.000	1.000	1.000
Mo friction modifier	---	0.120	---	0.120
DPA antioxidant	2.100	1.700	2.300	1.800
Sulfurized FAME	0.560	0.480	0.560	0.560
PIBSA 2000+ Mn	0.100	0.100	0.100	0.100
Polyisobutylene Mn 900+	0.300	0.300	0.300	0.300
Anti-foamant	0.005	0.005	0.005	0.005
Corrosion/rust inhibitor	---	---	---	---
Group I diluent oil	2.060	2.020	2.435	2.815
Treat rate wt %	18.800	18.400	19.200	19.200
Lube Oil Flow Improver	0.2	0.2	0.2	0.2
EP copolymer viscosity modifier	1	1	1	1
EHC 45 Group II+ base stock 115 VI	65	65.4	64.6	64.6
EHC 65 Group II base stock 105 VI	15	15	15	15
Predicted Properties				
SASH, %	0.86	0.86	0.85	0.85
S, %	0.3	0.3	0.31	0.32
P, %	0.08	0.08	0.08	0.08
Ca, %	0.12	0.12	0.12	0.12
Mg, %	0.08	0.08	0.08	0.08
Mg/Ca ratio	0.67	0.67	0.67	0.67
Mo, ppm	0	66	0	66
Predicted valve train rocker arm wear (mg), Ford 6.7L Power Stroke Diesel Engine Test	60-100	80-130	60-100	80-130
Predicted soot induced camshaft wear (µm) Cummins ISB Diesel Engine Test	25-45	25-45	25-45	25-45
Predicted soot dispersancy (%) ASTM D7156-19 12 cSt viscosity increase	5.7-6.7	6.0-7.0	5.7-6.7	5.7-6.7

Example 10

A. **4.12-F-H-Polyisoprene-A** - Amine functionalized hydrogenated isoprene polymer having an average functionality (Fv) of 4.12 was prepared using the same procedure used to make 7.15-F-H-Polyisoprene-A, except that the SA-H-Polyisoprene-A had a succinate functionality of 4.12. The 4.12-F-H-Polyisoprene-A had a Functionality Distribution (Fd)

value of 1.67, an Mw/Mn of 1.194, an Mn of 31,500, an Mz of 43,154 g/mol. Figure 3 shows the GPC trace (baseline indicated by triangle in abscissa and minimum point between peaks indicated by diamond in abscissa). 4.12-F-H-Polyisoprene-A can be used in blends similar to those using 4.0-F-H-Polyisoprene-A or 3.6-F-H-Polyisoprene-A above. For example, 4.12-F-H-Polyisoprene-A can be used in place of 4.0-F-H-Polyisoprene-A or 3.6-F-H-Polyisoprene-A above in examples 1 and 3 above.

B. 7.93-F-H-Polyisoprene-A -Amine functionalized hydrogenated isoprene polymer having an average functionality (Fv) of 7.93 was prepared using the same procedure used to make 7.15-F-H-Polyisoprene-A, except that the SA-H-Polyisoprene-A had a succinate functionality of 7.93. The 7.93-F-H-Polyisoprene-A had a Functionality Distribution (Fd) value of 2.36, an Mw/Mn of 1.277, an Mn of 33,627, and an Mz of 55,781 g/mol. Figure 4 shows the GPC trace (baseline indicated by triangle in abscissa and minimum point between peaks indicated by diamond in abscissa). 7.93-F-H-Polyisoprene-A can be used in blends similar to those using 7.0-F-H-Polyisoprene-A or 7.15-F-H-Polyisoprene-A above. For example, 7.93-F-H-Polyisoprene-A can be used in place of 7.0-F-H-Polyisoprene-A or 7.15-F-H-Polyisoprene-A in examples 1, 2, 3, 4, 5, 6, 7, 8, and 9, above.

C. F-EP-Copolymer B is a functionalized ethylene-propylene copolymer prepared by maleating ethylene-propylene copolymer (Trilene™ CP-80, Lion Elastomers, Mn approx 23,000 g/mol, E/P approx 41/59) then reacting with amine N-phenyl-p-phenylenediamine (ADPA) using the same method as above to obtain an ethylene-propylene copolymer containing one or more pendant amine groups and having an average functionality of 2.5, a Functionality Distribution (Fd) value of 3.77, an Mw/Mn of 1.588, an Mn of 19,147, and an Mz of 47,161 g/mol. Figure 5 shows the GPC trace (baseline indicated by triangle in abscissa and minimum point between peaks indicated by diamond in abscissa).

D. F-EP-Copolymer C is a functionalized ethylene-propylene copolymer prepared by maleating ethylene-propylene copolymer (Trilene™ CP-80, Lion Elastomers, Mn approx 23,000 g/mol, E/P approx 41/59) then reacting with amine N-phenyl-p-phenylenediamine (ADPA) using the same method as above to obtain an ethylene-propylene copolymer containing one or more pendant amine groups and having an average functionality of 4.68, a Functionality Distribution (Fd) value of 3.83, an Mw/Mn of 1.578, an Mn of 19,396, and an Mz of 47,559 g/mol. Figure 6 shows the GPC trace (baseline indicated by triangle in abscissa and minimum point between peaks indicated by diamond in abscissa).

[0489] All documents described herein are incorporated by reference herein, including any priority documents and/or testing procedures, to the extent they are not inconsistent with this

text. As is apparent from the foregoing general description and the specific embodiments, while forms of the invention have been illustrated and described, various modifications can be made without departing from the spirit and scope of the invention. Accordingly, it is not intended that the invention be limited thereby. The term "comprising" is considered synonymous with the term "including." Likewise, whenever a composition, an element, or a group of elements is preceded with the transitional phrase "comprising," it is understood that we also contemplate the same composition or group of elements with transitional phrases "consisting essentially of," "consisting of," "selected from the group of consisting of," or "is" preceding the recitation of the composition, element, or elements and vice versa.

Claims

What is claimed is:

1. An amide, imide, and/or ester functionalized partially or fully saturated polymer comprising C₄₋₅ olefins having:
 - i) an Mw/Mn of less than 2,
 - ii) a Functionality Distribution (Fd) value of 3.5 or less, and
 - iii) an Mn of 10,000 g/mol or more (GPC-PS) of the polymer prior to functionalization, provided that, if the polymer prior to functionalization is a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 25,000 g/mol (GPC-PS).
2. The functionalized polymer of claim 1, wherein the functionalized polymer comprises at least about 50 % of 1,4-insertions of monomer.
3. The functionalized polymer of claim 1, wherein the polymer prior to functionalization has an Mn of 25,000 g/mol or more (GPC-PS) or 30,000 g/mol or more (GPC-PS).
4. The functionalized polymer of claim 1, wherein the polymer prior to functionalization comprises at least 90 mol % isoprene repeat units or is homo-polyisoprene.
5. The functionalized polymer of claim 1, wherein the polymer is partially or fully hydrogenated prior to functionalization.
6. The functionalized polymer of claim 1, wherein the functionalized polymer comprises a partially or fully saturated homopolyisoprene having an Mn of 30,000 to 100,000 g/mol (GPC-PS), containing one or more pendant amine groups, and having at least about 50 %, such as at least about 60%, of 1,4-insertions prior to functionalization.
7. The functionalized polymer of claim 1, wherein, if the polymer prior to functionalization is homopolyisobutylene, then the C₄ olefin polymer has an Mn of 15,000 g/mol or more (GPC-PS), and if the polymer prior to functionalization is a copolymer of isoprene and butadiene, then the Mn of the copolymer is greater than 35,000 Mn (GPC-PS).

8. The functionalized polymer of claim 1, wherein the polymer prior to functionalization comprises 90 mol % or more isoprene repeat units or 100 mol % or more isoprene repeat units and has an Mn of 30,000 g/mol or more (GPC-PS).
9. The functionalized polymer of claim 1, wherein the polymer prior to functionalization is a partially or fully hydrogenated polymer of homopolyisoprene having an average functionality of 1 to 20 per 10,000 g/mol.
10. The functionalized polymer of claim 1, wherein:
- a) styrene repeat units are absent in the polymer; and or
 - b) butadiene repeat units are absent in the polymer; and or
 - c) the polymer is not homopolyisobutylene; and or
 - d) the polymer is not a copolymer of isoprene and butadiene.
11. The functionalized polymer of any of claims 1 to 10, wherein the polymer has an average functionality of 1.4 to 20 FG grafts/polymer chain, as determined by GPC-PS.
12. The functionalized polymer of any of claims 1 to 11, wherein the polymer is obtained by reacting fully or partially hydrogenated polymers of C₄₋₅ conjugated dienes having an Mw/Mn of less than 2 and an Mn of 10,000 g/mol or more, with an acylating agent and thereafter reacting the acylated polymer with an amine to form an imide, amide or combination thereof.
13. The functionalized polymer of claim 12, wherein side reactions are minimized, optionally, by adding the acylating agent in a continuous or semi-continuous fashion, and/or by introducing the fully or partially hydrogenated polymer into batch, semi-continuous, or continuous reactor operations as solution or suspension in diluent, said solution or suspension comprising 45 wt % or more of the fully or partially hydrogenated polymer, based upon the weight of the fully or partially hydrogenated polymer and diluent.
14. A lubricating oil composition comprising or resulting from the admixing of:
- (i) at least 50 mass % of one or more base oils, based upon the weight of the lubricating oil composition;
 - (ii) one or more dispersants;
 - (iii) one or more detergents; and

(iv) one or more functionalized polymers of any of claims 1 to 13.

15. A lubricating oil composition of claim 14, where the lubricating oil composition preferably has:

- a) an SAE viscosity grade of 20W-X, 15W-X, 10W-X, 5W-X, or 0W-X, where X represents any one of 8, 12, 16, 20, 30, 40, and 50, and
- b) soot induced wear of 55 mg or less (as determined by Cummins ISB test for valve train wear protection), and
- c) soot-induced viscosity increase of 12 cSt or less at 6 % soot (as determined by Mack T11 Test for Soot-Induced Viscosity Control).

16. A lubricating oil composition of claim 14 or 15, comprising or resulting from the admixing of:

- (i) from 50 to 99 mass % of the one or more base oils, based upon the weight of the lubricating oil composition;
- (ii) from 0.01 to 20 wt % based on total weight of the lubricating oil composition, of the one or more dispersants;
- (iii) from 0.10 to 20 mass %, based upon the weight of the lubricating oil composition, of the one or more detergents;
- (iv) from 0.10 to 20 mass %, based upon the weight of the lubricating oil composition, of the one or more functionalized polymers.

17. The lubricating oil composition of claim 14, further comprising one, two, three, four, five, six, or more of additional additives selected from the group consisting of: friction modifiers; antioxidants; pour point depressants; anti-foam agents; viscosity modifiers; inhibitors and/or anti-rust agents; and antiwear agents.

18. The lubricating oil composition of claim 16, further comprising one, two, three, four, five, six, or more of:

- D) from 0.01 to 5 wt %, based on total weight of the lubricating oil composition, of one or more friction modifiers;
- E) from 0.01 to 10 wt %, based on total weight of the lubricating oil composition, of one or more antioxidants;

- F) from 0.01 to 5 wt %, based on total weight of the lubricating oil composition, of one or more pour point depressants;
- G) from 0.001 to 5 wt %, based on total weight of the lubricating oil composition, of one or more anti-foam agents;
- H) from 0.001 to 10 wt %, based on total weight of the lubricating oil composition, of one or more viscosity modifiers;
- J) from 0.0 to 5 wt %, based on total weight of the lubricating oil composition, of one or more inhibitors and/or anti-rust agents; and/or
- K) from 0.001 to 10 wt %, based on total weight of the lubricating oil composition, of one or more antiwear agents.

19. The lubricating oil composition of claim 14, where the lubricating oil composition is absent phenolic antioxidant and/or styrenic polymer.

20. The lubricating oil composition of claim 14, where the lubricating oil composition comprises:

- 1) less than 5 mass % based on total weight of the lubricating oil composition, of functionalized oil; and or less
- 2) than 5 mass % based on total weight of the lubricating oil composition, of aliphatic or aromatic solvent; and or
- 3) less than 5 mass % based on total weight of the lubricating oil composition, of secondary hydrocarbyl amine compounds and tertiary hydrocarbyl amine compounds.

21. The lubricating oil composition claim 14, where the lubricating oil composition has a total Saponification Number (SAP) of 25 mgKOH/g or more as determined by ASTM D94 and the functionalized polymer has a Functionality Distribution (Fd) value of 3.5 or less.

22. The lubricating oil composition of claim 14, wherein :

- 1) the detergent comprises one or more oil-soluble neutral or overbased sulfonates, phenates, sulfurized phenates, thiophosphonates, salicylates, naphthenates and other oil-soluble carboxylates of a alkali or alkaline earth metal (such as sodium, potassium, lithium, calcium, and magnesium, such as Ca and/or Mg); and or

2) the dispersant comprises one or more borated or unborated poly(alkenyl)succinimides, where the polyalkenyl is derived from polyisobutylene and the imide is derived from a polyamine.

23. The lubricating oil composition claim 23, wherein the dispersant comprises one or more, optionally borated, higher molecular weight (M_n 1600 g/mol or more, such as 1800 to 3000 g/mol) poly(alkenyl)succinimide and one or more, optionally borated, lower molecular weight (M_n less than 1600 g/mol) poly(alkenyl)succinimide, where optionally the higher molecular weight poly(alkenyl)succinimide is present in the lubricating composition in an amount of 0.8 to 6 wt % and the lower molecular weight poly(alkenyl)succinimide is present in the lubricating composition in an amount of from 1.5 to 5 wt %.

24. The lubricating oil composition claim 14, wherein the lubricating oil composition is a heavy-duty diesel oil.

25. The lubricating oil composition of any of claims 14 to 24, wherein the soot-induced viscosity increase at 6 % soot is 12 cSt or less as determined by ASTM D7156-19; and or the camshaft wear is less than 50 μm as determined by ASTM D7484-21.

26. A method of lubricating an internal combustion engine during operation of the engine comprising:

- (i) providing to a crankcase of the internal combustion engine the lubricating composition of any of claims 14 to 25;
- (ii) providing a fuel, optionally a diesel fuel, in the internal combustion engine; and
- (iii) combusting the fuel in the automotive internal combustion engine.

27. The method of claim 25, wherein the fuel is one of more of hydrocarbon fuel, renewable fuel, hydrogen fuel or any blend thereof.

28. A fuel composition comprising the composition of any of claims 1 to 25 and one or more of hydrocarbon fuel, renewable fuel, hydrogen fuel, or any blend thereof.

29. A concentrate comprising or resulting from the admixing of from 1 to less than 50 mass % of one or more base oils; and from 0.10 to 20 mass %, based upon the weight of the concentrate,

of one or more of the functionalized polymers of any of claims 1 to 13, based upon the weight of the concentrate.