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(54) **LOW VISCOSITY LUBRICATING OIL
COMPOSITION**(71) Applicant: **Chevron Japan Ltd.**, San Ramon, CA
(US)(72) Inventors: **Hitoshi Ohkubo**, Makinohara (JP);
Koichi Kubo, Yokohama (JP); **Isao
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(57)

ABSTRACT

A lubricating oil composition having a high temperature high shear (HTHS) viscosity at 150° C. in a range of about 1.3 to about 2.3 cP is disclosed. The composition comprises (a) a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100° C. in a range of 1.5 to 6.0 mm²/s; and (b) a molybdenum-succinimide complex providing 200 to 1500 ppm by weight of molybdenum to the lubricating oil composition.

LOW VISCOSITY LUBRICATING OIL COMPOSITION

TECHNICAL FIELD

[0001] The disclosed technology relates to lubricants for internal combustion engines, particularly those for spark ignition engines.

BACKGROUND

[0002] Engine oil is blended with various additives in order to satisfy various performance requirements. One well known way to increase fuel economy is to decrease the viscosity of the lubricating oil. However, this approach is now reaching the limits of current equipment capabilities and specifications. At a given viscosity, it is well known that adding organic or organometallic friction modifiers reduces the surface friction of the lubricating oil and allows for better fuel economy. However, these additives often bring with them detrimental effects such as increased deposit formation, seals impacts, or they out-compete the anti-wear components for limited surface sites, thereby not allowing the formation of an anti-wear film, causing increased wear.

[0003] A major challenge in engine oil formulation is simultaneously achieving high temperature wear, deposit, and varnish control while also achieving improved fuel economy.

[0004] Despite the advances in lubricant oil formulation technology, there exists a need for a low viscosity engine oil lubricant suitable for both hybrid vehicles and direct injection engines that effectively improves fuel economy while maintaining or improving friction reduction properties and deposit control.

[0005] Compositions of molybdic acid and oil soluble basic nitrogen-containing compounds, such as molybdenum-succinimide complexes, have been used as lubricating oil additives to control oxidation and wear of engine components (see, e.g., U.S. Pat. Nos. 6,962,896 and 8,076,275). According to the present disclosure, lubricating oil compositions containing a molybdenum-succinimide complex exhibit friction reducing properties at lower viscosity grades (e.g., less than SAE 20) and thus provide improved fuel economy.

SUMMARY

[0006] In one aspect, there is provided a lubricating oil composition having a HTHS viscosity at 150° C. in a range of about 1.3 to about 2.3 cP, comprising: (a) a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100° C. in a range of 1.5 to 6.0 mm²/s; and (b) a molybdenum-succinimide complex providing 200 to 1500 ppm by weight of molybdenum to the lubricating oil composition.

[0007] In another aspect, there is provided a method of reducing friction in an engine lubricated with a lubricant by using as the lubricant the present lubricating oil composition.

[0008] In yet another aspect, there is provided a method of reducing wear in an engine lubricated with a lubricant by using as the lubricant the present lubricating oil composition.

[0009] In a further aspect, there is provided a method of improving fuel economy in an engine lubricated with a lubricant by using as the lubricant the present lubricating oil composition.

DETAILED DESCRIPTION

[0010] Various embodiments of the present disclosure provide lubricating oil compositions and methods for reducing friction and/or wear in an engine, particularly spark-ignited, direct injection and/or port fuel injection engines. The engine may be coupled to an electric motor/battery system in a hybrid vehicle (e.g., a port fuel injection spark ignition engine coupled to an electric motor/battery system in a hybrid vehicle).

Definitions

[0011] In this specification, the following words and expressions, if and when used, have the meanings given below.

[0012] A “major amount” means in excess of 50 weight % of a composition.

[0013] A “minor amount” means less than 50 weight % of a composition, expressed in respect of the stated additive and in respect of the total mass of all the additives present in the composition, reckoned as active ingredient of the additive or additives.

[0014] “Active ingredients” or “actives” refers to additive material that is not diluent or solvent.

[0015] All percentages reported are weight % on an active ingredient basis (i.e., without regard to carrier or diluent oil) unless otherwise stated.

[0016] The abbreviation “ppm” means parts per million by weight, based on the total weight of the lubricating oil composition.

[0017] Total base number (TBN) was determined in accordance with ASTM D2896.

[0018] High temperature high shear (HTHS) viscosity at 150° C. was determined in accordance with ASTM D4863.

[0019] Kinematic viscosity at 100° C. (KV₁₀₀) was determined in accordance with ASTM D445.

[0020] Cold Cranking Simulator (CCS) viscosity at -35° C. was determined in accordance with ASTM D5293.

[0021] Noack volatility was determined in accordance with ASTM D5800.

[0022] Boron, calcium, magnesium, molybdenum, phosphorus, sulfur, and zinc contents were determined in accordance with ASTM D5185.

[0023] Nitrogen content was determined in accordance with ASTM D4629.

[0024] All ASTM standards referred to herein are the most current versions as of the filing date of the present application.

Oil of Lubricating Viscosity

[0025] The oil of lubricating viscosity (sometimes referred to as “base stock” or “base oil”) is the primary liquid constituent of a lubricant, into which additives and possibly other oils are blended, for example to produce a final lubricant (or lubricant composition). A base oil is useful for making concentrates as well as for making lubricating oil compositions therefrom, and may be selected from natural and synthetic lubricating oils and combinations thereof.

[0026] Natural oils include animal and vegetable oils, liquid petroleum oils and hydrorefined, solvent-treated mineral lubricating oils of the paraffinic, naphthenic and mixed paraffinic-naphthenic types. Oils of lubricating viscosity derived from coal or shale are also useful base oils.

[0027] Synthetic lubricating oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes); alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)benzenes; polyphenols (e.g., biphenyls, terphenyls, alkylated polyphenols); and alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogues and homologues thereof.

[0028] Another suitable class of synthetic lubricating oils comprises the esters of dicarboxylic acids (e.g., malonic acid, alkyl malonic acids, alkenyl malonic acids, succinic acid, alkyl succinic acids and alkenyl succinic acids, maleic acid, fumaric acid, azelaic acid, suberic acid, sebacic acid, adipic acid, linoleic acid dimer, phthalic acid) with a variety of alcohols (e.g., 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.

[0029] Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols, and polyol ethers such as neopentyl glycol, trimethylolpropane, pentaerythritol, dipentaerythritol and tripentaerythritol.

[0030] The base oil may be derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are made from synthesis gas containing H₂ and CO using a Fischer-Tropsch catalyst. Such hydrocarbons typically require further processing in order to be useful as the base oil. For example, the hydrocarbons may be hydroisomerized; hydrocracked and hydroisomerized; dewaxed; or hydroisomerized and dewaxed; using processes known to those skilled in the art.

[0031] Unrefined, refined and re-refined oils can be used in the present lubricating oil composition. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. For example, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from distillation or ester oil obtained directly from an esterification process and used without further treatment would be unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques, such as distillation, solvent extraction, acid or base extraction, filtration and percolation are known to those skilled in the art. Re-refined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such re-refined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques for approval of spent additive and oil breakdown products.

[0032] Hence, the base oil which may be used to make the present lubricating oil composition may be selected from any of the base oils in Groups I-V as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines (API Publication 1509). Such base oil groups are summarized in Table 1 below:

TABLE 1

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

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

^(b)Determined in accordance with ASTM D2007.

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

^(d)Determined in accordance with ASTM D2270.

[0033] Base oils suitable for use herein are any of the variety corresponding to API Group II, Group III, Group IV, and Group V oils and combinations thereof, preferably the Group III to Group V oils due to their exceptional volatility, stability, viscometric and cleanliness features.

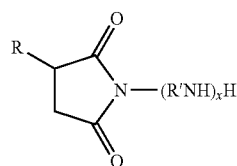
[0034] The base oil constitutes the major component of the present lubricating oil composition and is present in an amount ranging from greater than 50 to 99 wt. % (e.g., 70 to 95 wt. %, or 85 to 95 wt. %).

[0035] The base oil may be selected from any of the synthetic or natural oils typically used as crankcase lubricating oils for spark-ignited internal combustion engines. The base oil typically has a kinematic viscosity at 100° C. in a range of 1.5 to 6 mm²/s. In the case where the kinematic viscosity at 100° C. of the lubricating base oil exceeds 6 mm²/s, low temperature viscosity properties may be reduced, and sufficient fuel efficiency may not be obtained. At a kinematic viscosity of 1.5 mm²/s or less, formation of an oil film in a lubrication place is insufficient; for this reason, lubrication is inferior, and the evaporation loss of the lubricating oil composition may be increased.

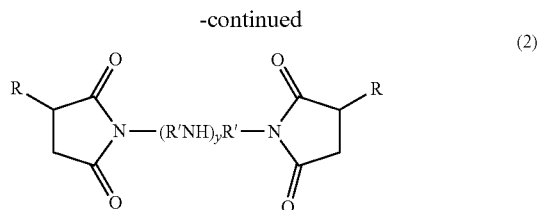
[0036] Preferably, the base oil has a viscosity index of at least 90 (e.g., at least 95, at least 105, at least 110, at least 115, or at least 120). If the viscosity index is less than 90, not only viscosity-temperature properties, heat and oxidation stability, and anti-volatilization are reduced, but also the coefficient of friction tends to be increased; and resistance against wear tends to be reduced.

Molybdenum-Succinimide Complex

[0037] Suitable molybdenum-succinimide complexes are described, for example, in U.S. Pat. No. 8,076,275. These complexes are prepared by a process comprising reacting an acidic molybdenum compound with an alkyl or alkenyl succinimide of a polyamine of structure (1) or (2) or mixtures thereof:



(1)



wherein R is a C_{24} to C_{350} (e.g., C_{70} to C_{128}) alkyl or alkenyl group; R' is a straight or branched-chain alkylene group having 2 to 3 carbon atoms; x is 1 to 11; and y is 1 to 10.

[0038] The molybdenum compounds used to prepare the molybdenum-succinimide complex are acidic molybdenum compounds or salts of acidic molybdenum compounds. By "acidic" is meant that the molybdenum compounds will react with a basic nitrogen compound as measured by ASTM D664 or D2896. Generally, the acidic molybdenum compounds are hexavalent. Representative examples of suitable molybdenum compounds include molybdenum trioxide, molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdate and other alkaline metal molybdates and other molybdenum salts such as hydrogen salts, (e.g., hydrogen sodium molybdate), $MoOCl_4$, MoO_2Br_2 , $Mo_2O_3Cl_6$, and the like.

[0039] The succinimides that can be used to prepare the molybdenum-succinimide complex are disclosed in numerous references and are well known in the art. Certain fundamental types of succinimides and the related materials encompassed by the term of art "succinimide" are taught in U.S. Pat. Nos. 3,172,892; 3,219,666; and 3,272,746. The term "succinimide" is understood in the art to include many of the amide, imide, and amidine species which may also be formed. The predominant product however is a succinimide and this term has been generally accepted as meaning the product of a reaction of an alkyl or alkenyl substituted succinic acid or anhydride with a nitrogen-containing compound. Preferred succinimides are those prepared by reacting a polyisobutenyl succinic anhydride of about 70 to 128 carbon atoms with a polyalkylene polyamine selected from triethylenetetramine, tetraethylenepentamine, and mixtures thereof.

[0040] The molybdenum-succinimide complex may be post-treated with a sulfur source at a suitable pressure and a temperature not to exceed $120^\circ C$. to provide a sulfurized molybdenum-succinimide complex. The sulfurization step may be carried out for a period of from about 0.5 to 5 hours (e.g., 0.5 to 2 hours). Suitable sources of sulfur include elemental sulfur, hydrogen sulfide, phosphorus pentasulfide, organic polysulfides of formula R_2S_x where R is hydrocarbyl (e.g., C_1 to C_{10} alkyl) and x is at least 3, C_1 to C_{10} mercaptans, inorganic sulfides and polysulfides, thioacetamide, and thiourea.

[0041] The molybdenum-succinimide complex is used in an amount that provides at least 200 ppm (e.g., 200 to 1500 ppm, 200 to 1100 ppm, 250 to 1500 ppm, 250 to 1100 ppm, or 300 to 1000 ppm) by weight of molybdenum to the lubricating oil composition.

Detergent Mixture

[0042] The lubricating oil composition may also include a detergent mixture which comprises at least one calcium-containing detergent and at least one magnesium-containing detergent.

[0043] A typical detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the detergent is typically derived from an organic acid such as a sulfur acid, carboxylic acid, phosphorous acid, phenol, or mixtures thereof. The counterion is typically an alkaline earth or alkali metal.

[0044] Salts that contain a substantially stoichiometric amount of the metal are described as neutral salts and have a total base number (TBN) of from 0 to 80 mg KOH/g. Many compositions are overbased, containing large amounts of a metal base that is achieved by reacting an excess of a metal compound (e.g., a metal hydroxide or oxide) rich an acidic gas (e.g., carbon dioxide). Useful detergents can be neutral, mildly overbased, or highly overbased.

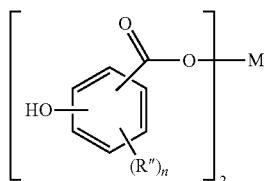
[0045] It is desirable for at least some detergent used in the detergent mixture to be overbased. Overbased detergents help neutralize acidic impurities produced by the combustion process and become entrapped in the oil. Typically, the overbased material has a ratio of metallic ion to anionic portion of the detergent of 1.05:1 to 50:1 (e.g., 4:1 to 25:1) on an equivalent basis. The resulting detergent is an over-based detergent that will typically have a TBN of 150 mg KOH/g or higher (e.g., 250 to 450 mg KOH/g or more). A mixture of detergents of differing TBN can be used.

[0046] Suitable detergents include metal salts of sulfonates, phenates, carboxylates, phosphates, and salicylates.

[0047] Sulfonates may be prepared from sulfonic acids which are typically obtained by the sulfonation of alkyl-substituted aromatic hydrocarbons such as those obtained from the fractionation of petroleum or by the alkylation of aromatic hydrocarbons. Examples included those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl or their halogen derivatives. The alkylation may be carried out in the presence of a catalyst with alkylating agents having from about 3 to more than 70 carbon atoms. The alkaryl sulfonates usually contain from about 9 to 80 or more carbon atoms (e.g., about 16 to 60 carbon atoms) per alkyl substituted aromatic moiety.

[0048] Phenates can be prepared by reacting an alkaline earth metal hydroxide or oxide (e.g., CaO, $Ca(OH)_2$, MgO, or $Mg(OH)_2$) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight or branched chain C_1 to C_{30} (e.g., C_4 to C_{20}) alkyl groups, or mixtures thereof. Examples of suitable phenols include isobutylphenol, 2-ethylhexylphenol, nonylphenol, dodecyl phenol, and the like. It should be noted that starting alkylphenols may contain more than one alkyl substituent that are each independently straight chain or branched chain. When a non-sulfurized alkylphenol is used, the sulfurized product may be obtained by methods well known in the art. These methods include heating a mixture of alkylphenol and sulfurizing agent (e.g., elemental sulfur, sulfur halides such as sulfur dichloride, and the like) and then reacting the sulfurized phenol with an alkaline earth metal base.

[0049] Salicylates may be prepared by reacting a basic metal compound with at least one carboxylic acid and removing water from the reaction product. Detergents made from salicylic acid are one class of detergents prepared from carboxylic acids. Useful salicylates include long chain alkyl salicylates. One useful family of compositions is of the following structure (3):



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

[0050] Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction (see U.S. Pat. No. 3,595,791). The metal salts of the hydrocarbyl-substituted salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent such as water or alcohol.

[0051] Alkaline earth metal phosphates are also used as detergents and are known in the art.

[0052] Preferred calcium-containing detergents include calcium sulfonates, calcium phenates, and calcium salicylates, especially calcium sulfonates, calcium salicylates, and mixtures thereof.

[0053] The calcium-containing detergent may be used in an amount that provides at least 750 ppm (e.g., 750 to 3000 ppm, 750 to 2000 ppm, 1000 to 3000 ppm, or 1000 to 2000 ppm) by weight of calcium to the lubricating oil composition.

[0054] Preferred magnesium-containing detergents include magnesium sulfonates, magnesium phenates, and magnesium salicylates, especially magnesium sulfonates.

[0055] The magnesium-containing detergent may be used in an amount that provides at least 200 ppm (e.g., 200 to 1000 ppm, 200 to 800 ppm, 300 to 1000 ppm, 300 to 800 ppm, 400 to 1000 ppm, or 400 to 800 ppm) by weight of magnesium to the lubricating oil composition.

[0056] The mass ratio of calcium to magnesium in the lubricating oil composition is greater than 1 (e.g., 1.5 to 3.5, or 2 to 3).

Viscosity Modifier

[0057] The lubricating oil composition may also include a viscosity modifier. Viscosity modifiers function to impart high and low temperature operability to a lubricating oil. The viscosity modifier used may have that sole function, or may be multifunctional. Multifunctional viscosity modifiers that also function as dispersants are also known. Suitable viscosity modifiers include polyisobutylene, copolymers of ethylene and propylene and higher alpha-olefins, polymethacrylates, polyalkylmethacrylates, methacrylate copolymers, copolymers of an unsaturated dicarboxylic acid and a vinyl compound, interpolymers of styrene and acrylic esters, and partially hydrogenated copolymers of styrene/isoprene, styrene/butadiene, and isoprene/butadiene, as well as the partially hydrogenated homopolymers of butadiene and isoprene and isoprene/divinylbenzene. In one embodiment, the viscosity modifier is a polyalkylmethacrylate. The topology of the viscosity modifier could include, but is not limited to, linear, branched, hyperbranched, star, or comb topology.

[0058] Suitable viscosity modifiers have a Permanent Shear Stability Index (PSSI) of 30 or less (e.g., 10 or less, 5 or less, or even 2 or less). PSSI is a measure of the

irreversible decrease, resulting from shear, in an oil's viscosity contributed by an additive. PSSI is determined according to ASTM D6022. The lubricating oil compositions of the present disclosure display stay-in-grade capability. Retention of kinematic viscosity at 100° C. within a single SAE viscosity grade classification by a fresh oil and its sheared version is evidence of an oil's stay-in-grade capability.

[0059] The viscosity modifier may be used in an amount of from 0.5 to 15.0 wt. % (e.g., 0.5 to 10 wt. %, 0.5 to 5 wt. %, 1.0 to 15 wt. %, 1.0 to 10 wt. %, or 1.0 to 5 wt. %), based on the total weight of the lubricating oil composition.

Lubricating Oil Composition

[0060] The lubricating oil composition may be a multi-grade oil identified by the viscosity grade descriptor SAE OW-X, wherein X represents any one of 8, 12, and 16.

[0061] The lubricating oil composition has a high temperature shear (HTHS) viscosity at 150° C. of 2.3 cP or less (e.g., 1.0 to 2.6 cP, or 1.3 to 2.3 cP), such as 2.0 cP or less (e.g., 1.0 to 2.0 cP, or 1.3 to 2.3 cP), or even 1.7 cP or less (e.g., 1.0 to 1.7 cP, or 1.3 to 1.7 cP).

[0062] The lubricating oil composition has a viscosity index of at least 135 (e.g., 135 to 400, or 135 to 250), at least 150 (e.g., 150 to 400, 150 to 250), at least 165 (e.g., 165 to 400, or 165 to 250), at least 190 (e.g., 190 to 400, or 190 to 250), or at least 200 (e.g., 200 to 400, or 200 to 250). If the viscosity index of the lubricating oil composition is less than 135, it may be difficult to improve fuel efficiency while maintaining the HTHS viscosity at 150° C. If the viscosity index of the lubricating oil composition exceeds 400, evaporation properties may be reduced, and deficits due to insufficient solubility of the additive and matching properties with a seal material may be caused.

[0063] The lubricating oil composition has a kinematic viscosity at 100° C. in a range of 3 to 12 mm²/s (e.g., 3 to 6.9 mm²/s, 3.5 to 6.9 mm²/s, or 4 to 6.9 mm²/s).

[0064] The lubricating oil composition may contain low levels of phosphorus. The lubricating oil composition may have a phosphorus content of 0.12 wt. % or less (e.g., 0.10 wt. % or less, 0.04 to 0.12 wt. %, or 0.04 to 0.10 wt. %), expressed as atoms of phosphorus, based on the total weight of the composition.

[0065] The lubricating oil composition may contain low levels of sulfur. The lubricating oil composition may have a sulfur content of 0.5 wt. % or less (e.g., 0.4 wt. % or less, 0.3 wt. % or less, or 0.2 wt. % or less), expressed as atoms of sulfur, based on the total weight of the composition.

[0066] Suitably, the present lubricating oil composition may have a total base number (TBN) of 4 to 15 mg KOH/g (e.g., 5 to 12 mg KOH/g, 6 to 12 mg KOH/g, or 8 to 12 mg KOH/g).

Additional Co-Additives

[0067] The present lubricating oil composition may additionally contain one or more of the other commonly used lubricating oil performance co-additives including dispersants, antiwear agents, antioxidants, friction modifiers, corrosion inhibitors, foam inhibitors, pour point depressants, and others.

Dispersants

[0068] Dispersants maintain in suspension materials resulting from oxidation during engine operation that are insoluble in oil, thus preventing sludge flocculation and precipitation or deposition on metal parts. Dispersants useful herein include nitrogen-containing, ashless (metal-free) dispersants known to be effective to reduce formation of deposits upon use in gasoline and diesel engines.

[0069] Suitable dispersants include hydrocarbyl succinimides, hydrocarbyl succinamides, mixed ester/amides of hydrocarbyl-substituted succinic acid, hydroxyesters of hydrocarbyl-substituted succinic acid, and Mannich condensation products of hydrocarbyl-substituted phenols, formaldehyde and polyamines. Also suitable are condensation products of polyamines and hydrocarbyl-substituted phenyl acids. Mixtures of these dispersants can also be used.

[0070] Basic nitrogen-containing ashless dispersants are well-known lubricating oil additives and methods for their preparation are extensively described in the patent literature. Preferred dispersants are the alkenyl succinimides and succinamides where the alkenyl-substituent is a long-chain of preferably greater than 40 carbon atoms. These materials are readily made by reacting a hydrocarbyl-substituted dicarboxylic acid material with a molecule containing amine functionality. Examples of suitable amines are polyamines such as polyalkylene polyamines, hydroxy-substituted polyamines and polyoxyalkylene polyamines.

[0071] Particularly preferred ashless dispersants are the polyisobutenyl succinimides formed from polyisobutenyl succinic anhydride and a polyalkylene polyamine such as a polyethylene polyamine of formula:



wherein z is 1 to 11. The polyisobutenyl group is derived from polyisobutene and preferably has a number average molecular weight (M_n) in a range of 700 to 3000 Daltons (e.g., 900 to 2500 Daltons). For example, the polyisobutenyl succinimide may be a bis-succinimide derived from a polyisobutenyl group having a M_n of 900 to 2500 Daltons.

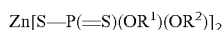
[0072] As is known in the art, the dispersants may be post-treated (e.g., with a boronating agent or a cyclic carbonate).

[0073] Nitrogen-containing ashless (metal-free) dispersants are basic, and contribute to the TBN of a lubricating oil composition to which they are added, without introducing additional sulfated ash.

[0074] Dispersants may be present at 0.1 to 10 wt. % (e.g., 2 to 5 wt. %) of the lubricating oil composition.

Antiwear Agents

[0075] Antiwear agents reduce wear of metal parts. Suitable anti-wear agents include dihydrocarbyl dithiophosphate metal salts such as zinc dihydrocarbyl dithiophosphates (ZDDP) of formula:



wherein R^1 and R^2 may be the same or different hydrocarbyl radicals having from 1 to 18 (e.g., 2 to 12) carbon atoms and including radicals such as alkyl, alkenyl, aryl, arylalkyl, alkaryl and cycloaliphatic radicals. Particularly preferred as R^1 and R^2 groups are alkyl groups having from 2 to 8 carbon atoms (e.g., the alkyl radicals may be ethyl, *n*-propyl, isopropyl, *n*-butyl, isobutyl, sec-butyl, *n*-pentyl, isopentyl, *n*-hexyl, isohexyl, 2-ethylhexyl). In order to obtain oil

solubility, the total number of carbon atoms (i.e., $\text{R}^1 + \text{R}^2$) will be at least 5. The zinc dihydrocarbyl dithiophosphate can therefore comprise zinc dialkyl dithiophosphates. Preferably, the zinc dialkyl dithiophosphate is a secondary zinc dialkyl dithiophosphate.

[0076] ZDDP may be present at 3 wt. % or less (e.g., 0.1 to 1.5 wt. %, or 0.5 to 1.0 wt. %) of the lubricating oil composition.

Antioxidants

[0077] Antioxidants reduce the tendency of mineral oils during to deteriorate during service. Oxidative deterioration can be evidenced by sludge in the lubricant, varnish-like deposits on the metal surfaces, and by viscosity growth. Suitable antioxidants include hindered phenols, aromatic amines, and sulfurized alkylphenols and alkali and alkaline earth metals salts thereof.

[0078] The hindered phenol antioxidant often contains a secondary butyl and/or a tertiary butyl group as a sterically hindering group. The phenol group may be further substituted with a hydrocarbyl group (typically linear or branched alkyl) and/or a bridging group linking to a second aromatic group. Examples of suitable hindered phenol antioxidants include 2,6-di-*tert*-butylphenol; 4-methyl-2,6-di-*tert*-butylphenol; 4-ethyl-2,6-di-*tert*-butylphenol; 4-propyl-2,6-di-*tert*-butylphenol; 4-butyl-2,6-di-*tert*-butylphenol; and 4-dodecyl-2,6-di-*tert*-butylphenol. Other useful hindered phenol antioxidants include 2,6-di-alkyl-phenolic propionic ester derivatives such as IRGANOX® L-135 from Ciba and bis-phenolic antioxidants such as 4,4'-bis(2,6-di-*tert*-butylphenol) and 4,4'-methylenebis(2,6-di-*tert*-butylphenol).

[0079] Typical aromatic amine antioxidants have at least two aromatic groups attached directly to one amine nitrogen. Typical aromatic amine antioxidants have alkyl substituent groups of at least 6 carbon atoms. Particular examples of aromatic amine antioxidants useful herein include 4,4'-diocetyldiphenylamine, 4,4'-dinonyldiphenylamine, *N*-phenyl-1-naphthylamine, *N*-(4-*tert*-octylphenyl)-1-naphthylamine, and *N*-(4-octylphenyl)-1-naphthylamine.

[0080] Antioxidants may be present at 0.01 to 5 wt. % (e.g., 0.1 to 2 wt. %) of the lubricating oil composition.

Friction Modifiers

[0081] A friction modifier is any material that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material. Suitable friction modifiers long chain fatty acid derivatives of amines, long chain fatty esters, or derivatives of a long chain fatty epoxides; fatty imidazolines; and amine salts of alkylphosphoric acids. As used herein, the term "fatty" means a carbon chain having 10 to 22 carbon atoms, typically a straight carbon chain.

[0082] Friction modifiers may be present at 0.01 to 5 wt. % (e.g., 0.1 to 1.5 wt. %) of the lubricating oil composition.

Corrosion Inhibitors

[0083] Corrosion inhibitors protect lubricated metal surfaces against chemical attack by water or other contaminants. Suitable corrosion inhibitors include polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, thiadiazoles and anionic alkyl sulfonic acids. Such additives may be present at 0.01 to 5 wt. % (e.g., 0.1 to 1.5 wt. %) of the lubricating oil composition.

Foam Inhibitors

[0084] Foam control can be provided by many compounds including a foam inhibitor of the polysiloxane type (e.g., silicone oil or polydimethyl siloxane). Foam inhibitors may be present at less than 0.1 wt. % (e.g., 0.0001 to 0.01 wt. %) of the lubricating oil composition.

Pour Point Depressants

[0085] Pour point depressants lower the minimum temperature at which a fluid will flow or can be poured. Suitable pour point depressants include C8 to C18 dialkyl fumarate/vinyl acetate copolymers, polyalkylmethacrylates and the like. Such additives may be present at 0.01 to 5 wt. % (e.g., 0.1 to 1.5 wt. %) of the lubricating oil composition.

EXAMPLES

[0086] The following illustrative examples are intended to be non-limiting.

Example 1

[0087] A lubricating oil composition was prepared that contained a major amount of a base oil of lubricating viscosity and the following additives, to provide a finished oil having a HTHS viscosity at 150° C. of 1.5 cP:

- [0088]** (1) 2.4 wt. % of an ethylene carbonate post-treated bis-succinimide;
- [0089]** (2) 1 wt. % of a borated bis-succinimide dispersant;
- [0090]** (3) 0.14 wt. % in terms of calcium content, of a mixture of a 17 TBN calcium sulfonate detergent, a 168 TBN calcium salicylate detergent, and a 323 TBN calcium salicylate detergent;
- [0091]** (4) 510 ppm in terms of magnesium content, of a 400 TBN magnesium sulfonate detergent;
- [0092]** (5) 740 ppm in terms of phosphorus content, of a mixture of a primary zinc dialkyldithiophosphate and a secondary zinc dialkyldithiophosphate;
- [0093]** (6) 1.4 wt. % of an alkylated diphenylamine;
- [0094]** (7) 5 ppm in terms of silicon content, of a foam inhibitor;
- [0095]** (8) 3.0 wt. % of a polyalkylmethacrylate viscosity modifier having a PSSI of 1; and
- [0096]** (9) the remainder, a Group II base oil (YUBASE 2).

Example 2

[0097] A lubricating oil was prepared in accordance with the formulation of Example 1 except that a molybdenum-succinimide complex was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

[0098] The succinimide of the molybdenum-succinimide complex was prepared from polyisobutenyl (1000 MW) succinic anhydride and a mixture of polyethylene polyamine oligomers.

Example 3

[0099] A lubricating oil was prepared in accordance with the formulation of Example 2 except that the molybdenum-succinimide complex was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 4

[0100] A lubricating oil was prepared in accordance with the formulation of Example 1 except that a molybdenum dithiocarbamate (SAKURA-LUBE® 151; ADEKA Corporation) was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

Example 5

[0101] A lubricating oil was prepared in accordance with the formulation of Example 4 except that the molybdenum dithiocarbamate was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 6

[0102] A lubricating oil was prepared in accordance with the formulation of Example 1 except that a molybdenum ester/amide (MOLYVAN® 855; Vanderbilt Chemicals) was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

Example 7

[0103] A lubricating oil was prepared in accordance with the formulation of Example 6 except that the molybdenum ester/amide was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 8

[0104] A lubricating oil composition was prepared that contained a major amount of a base oil of lubricating viscosity and the following additives, to provide an SAE OW-8 finished oil:

- [0105]** (1) 2.4 wt. % of an ethylene carbonate post-treated bis-succinimide;
- [0106]** (2) 1 wt. % of a borated bis-succinimide dispersant;
- [0107]** (3) 0.14 wt. % in terms of calcium content, of a mixture of a 17 TBN calcium sulfonate detergent, a 168 TBN calcium salicylate detergent, and a 323 TBN calcium salicylate detergent;
- [0108]** (4) 510 ppm in terms of magnesium content, of a 400 TBN magnesium sulfonate detergent;
- [0109]** (5) 740 ppm in terms of phosphorus content, of a mixture of a primary zinc dialkyldithiophosphate and a secondary zinc dialkyldithiophosphate;
- [0110]** (6) 1.4 wt. % of an alkylated diphenylamine;
- [0111]** (7) 5 ppm in terms of silicon content, of a foam inhibitor;
- [0112]** (8) 3.5 wt. % of a polyalkylmethacrylate viscosity modifier having a PSSI of 1; and
- [0113]** (9) the remainder, a Group II base oil (YUBASE® 3).

Example 9

[0114] A lubricating oil was prepared in accordance with the formulation of Example 8 except that a molybdenum-succinimide complex was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

[0115] The succinimide of the molybdenum-succinimide complex was prepared from polyisobutenyl (1000 MW) succinic anhydride and a mixture of polyethylene polyamine oligomers.

Example 10

[0116] A lubricating oil was prepared in accordance with the formulation of Example 9 except that the molybdenum-succinimide complex was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 11

[0117] A lubricating oil was prepared in accordance with the formulation of Example 8 except that a molybdenum dithiocarbamate (SAKURA-LUBE® 151; ADEKA Corporation) was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

Example 12

[0118] A lubricating oil was prepared in accordance with the formulation of Example 11 except that the molybdenum dithiocarbamate was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 13

[0119] A lubricating oil was prepared in accordance with the formulation of Example 8 except that a molybdenum ester/amide (MOLYVAN® 855; Vanderbilt Chemicals) was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

Example 14

[0120] A lubricating oil was prepared in accordance with the formulation of Example 13 except that the molybdenum ester/amide was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 15

[0121] A lubricating oil composition was prepared that contained a major amount of a base oil of lubricating viscosity and the following additives, to provide an SAE OW-12 finished oil:

- [0122] (1) 2.4 wt. % of an ethylene carbonate post-treated bis-succinimide;
- [0123] (2) 1 wt. % of a borated bis-succinimide dispersant;
- [0124] (3) 0.14 wt. % in terms of calcium content, of a mixture of a 17 TBN calcium sulfonate detergent, a 168 TBN calcium salicylate detergent, and a 323 TBN calcium salicylate detergent;
- [0125] (4) 510 ppm in terms of magnesium content, of a 400 TBN magnesium sulfonate detergent;
- [0126] (5) 740 ppm in terms of phosphorus content, of a mixture of a primary zinc dialkyldithiophosphate and a secondary zinc dialkyldithiophosphate;
- [0127] (6) 1.4 wt. % of an alkylated diphenylamine;
- [0128] (7) 5 ppm in terms of silicon content, of a foam inhibitor;
- [0129] (8) 2.0 wt. % of a polyalkylmethacrylate viscosity modifier having a PSSI of 1; and
- [0130] (9) the remainder, a Group III base oil (YUBASE® 4).

Example 16

[0131] A lubricating oil was prepared in accordance with the formulation of Example 15 except that a molybdenum-

succinimide complex was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

[0132] The succinimide of the molybdenum-succinimide complex was prepared from polyisobutenyl (1000 MW) succinic anhydride and a mixture of polyethylene polyamine oligomers.

Example 17

[0133] A lubricating oil was prepared in accordance with the formulation of Example 16 except that a molybdenum-succinimide complex was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 18

[0134] A lubricating oil was prepared in accordance with the formulation of Example 15 except that a molybdenum dithiocarbamate (SAKURA-LUBE® 151; ADEKA Corporation) was added to provide 300 ppm by weight of molybdenum to the lubricating oil composition.

Example 19

[0135] A lubricating oil was prepared in accordance with the formulation of Example 18 except that the molybdenum dithiocarbamate was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Example 20

[0136] A lubricating oil was prepared in accordance with the formulation of Example 15 except that a molybdenum ester/amide (MOLYVAN® 855; Vanderbilt Chemicals) was added. The composition contained 300 ppm molybdenum based on the total weight of the lubricating oil composition.

Example 21

[0137] A lubricating oil was prepared in accordance with the formulation of Example 20 except that the molybdenum ester/amide was added to provide 1000 ppm by weight of molybdenum to the lubricating oil composition.

Testing

[0138] The lubricating oil compositions were evaluated in the Komatsu Hot Tube Test, the SRV Friction Test and the Shell Four Ball Wear Test to assess their performance.

[0139] Detergency and thermal and oxidative stability are performance areas that are generally accepted in the industry as being essential to satisfactory overall performance of a lubricating oil. The Komatsu Hot Tube test is a lubrication industry bench test (JPI 5S-55-99) that measures the detergency and thermal and oxidative stability of a lubricating oil. During the test, a specified amount of test oil is pumped upwards through a glass tube that is placed inside an oven set at a certain temperature. Air is introduced in the oil stream before the oil enters the glass tube, and flows upward with the oil. Evaluations of the lubricating oils were conducted at a temperature of 280° C. The test result is determined by comparing the amount of lacquer deposited on the glass test tube to a rating scale ranging from 1.0 (very black) to 10.0 (perfectly clean).

[0140] The friction reducing performance of each lubricating oil composition was evaluated by means of a cylinder-on-desk reciprocating sliding tester (SRV manufactured by Optimol) under conditions of 400 N of load, 0.4 GPa of

surface pressure (maximum Hertz stress), 10 Hz of frequency, 1.50 mm of amplitude, 100° C. of temperature, 60 minutes of testing time. The friction characteristic was evaluated by calculating the average friction coefficient which is an averaged friction coefficient for the time of 30 to 60 minutes after beginning of the test. This measurement conditions correspond to the conditions of boundary lubrication.

[0141] The wear preventative performance of each lubricating oil composition was determined in accordance with ASTM D4172 under conditions of 1200 rpm, oil temperature of 80° C. and load of 30 kgf for periods of 30 minutes. After testing, the test balls were removed, the wear scars were measured and the diameter shown as the result.

[0142] The properties and performance results of the lubricating oil compositions having a HTHS viscosity at 150° C. of 1.5 cP (Examples 1-7) are summarized in Table 2 below.

[0143] The properties and performance results of the SAE 0W-8 viscosity grade lubricating oil compositions (Examples 8-14) are summarized in Table 3 below.

[0144] The properties and performance results of the SAE 0W-12 viscosity grade lubricating oil compositions (Examples 15-21) are summarized in Table 4 below.

[0145] As shown in Tables 2-4, lubricating oil compositions containing a Mo-succinimide complex (Examples 2-3, 9-10, and 16-17) provide comparable or superior friction reducing properties to lubricating oil compositions containing conventional organomolybdenum friction modifiers at very low viscosity grades while maintaining wear and detergency performance. Lubricating oils containing the molybdenum ester/amide exhibited the poorest friction reducing properties.

TABLE 2

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7
Mo, ppm	—	—	—	—	—	300	1000
Mo ester/amide	—	—	—	300	1000	—	—
MoDTC	—	—	—	—	—	—	—
Mo-succinimide	—	300	1000	—	—	—	—
Kinematic Viscosity (100° C.), mm ² /s	3.9	4.0	4.2	3.9	4.0	3.9	4.0
Viscosity Index	208	209	210	207	206	206	207
CCS Viscosity (−35° C.), cP	1002	1035	1125	985	1024	1026	1076
HTHS Viscosity (150° C.), cP	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Noack Volatility, %	60	60	60	60	60	60	60
P, wt. %	0.074	0.074	0.074	0.074	0.074	0.074	0.074
S, wt. %	0.18	0.18	0.19	0.21	0.29	0.18	0.18
Zn, wt. %	0.088	0.088	0.088	0.088	0.088	0.088	0.088
Ca, wt. %	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Mg, wt. %	0.051	0.051	0.051	0.051	0.051	0.051	0.051
B, wt. %	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Mo, wt. %	—	0.030	0.10	0.030	0.10	0.030	0.10
N, wt. %	0.09	0.11	0.14	0.10	0.11	0.10	0.13
Ca/Mg mass ratio	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Komatsu Hot Tube Test							
Merit Rating ^(a)	8.5	8.0	6.0	8.5	6.5	8.5	6.5
SRV Friction Test							
Coefficient of Friction	0.17	0.073	0.043	0.067	0.050	0.086	0.068
Shell 4 Ball Wear Test							
Wear Scar Diameter, mm	0.39	0.39	0.38	0.44	0.39	0.45	0.39

^(a)Merit rating >7 (Good); Merit Rating = 6-7 (Marginally Acceptable); and Merit Rating <6 (Poor)

TABLE 3

	Ex. 8	Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14
SAE Viscosity Grade	0W-8	0W-8	0W-8	0W-8	0W-8	0W-8	0W-8
Mo, ppm	—	—	—	—	—	300	1000
Mo ester/amide	—	—	—	300	1000	—	—
MoDTC	—	—	—	—	—	—	—
Mo-succinimide	—	300	1000	—	—	—	—
Kinematic Viscosity (100° C.), mm ² /s	4.8	4.9	5.2	4.8	4.9	4.8	4.9
Viscosity Index	205	207	209	205	206	206	206
CCS Viscosity (−35° C.), cP	1898	1954	2106	1907	1923	1957	2012
HTHS Viscosity (150° C.), cP	1.8	1.8	1.9	1.8	1.8	1.7	1.8
Noack Volatility, %	37	37	37	37	37	37	37
P, wt. %	0.074	0.074	0.074	0.074	0.074	0.074	0.074
S, wt. %	0.18	0.18	0.19	0.21	0.29	0.18	0.18
Zn, wt. %	0.088	0.088	0.088	0.088	0.088	0.088	0.088
Ca, wt. %	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Mg, wt. %	0.051	0.051	0.051	0.051	0.051	0.051	0.051
B, wt. %	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Mo, wt. %	—	0.030	0.10	0.030	0.10	0.030	0.10

TABLE 3-continued

	Ex. 8	Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14
N, wt. %	0.09	0.11	0.14	0.10	0.11	0.10	0.13
Ca/Mg mass ratio	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Komatsu Hot Tube Test							
Merit Rating ^(a)	8.5	8.5	7.0	8.5	7.0	8.5	6.5
SRV Friction Test							
Coefficient of Friction	0.17	0.071	0.042	0.058	0.053	0.109	0.069
Shell 4 Ball Wear Test							
Wear Scar Diameter, mm	0.39	0.44	0.42	0.38	0.41	0.40	0.39

^(a)Merit rating >7 (Good); Merit Rating = 6-7 (Marginally Acceptable); and Merit Rating <6 (Poor)

TABLE 4

	Ex. 15	Ex. 16	Ex. 17	Ex. 18	Ex. 19	Ex. 20	Ex. 21
SAE Viscosity Grade	0W-12	0W-12	0W-12	0W-12	0W-12	0W-12	0W-12
Mo, Mo ester/amide	—	—	—	—	—	300	1000
ppm MoDTC	—	—	—	300	1000	—	—
Mo-succinimide	—	300	1000	—	—	—	—
Kinematic Viscosity (100° C.), mm ² /s	5.6	5.7	6.0	5.6	5.7	5.6	5.7
Viscosity Index	166	167	168	166	166	164	168
CCS Viscosity (−35° C.), cP	4478	4621	4960	4506	4549	4561	4737
HTHS Viscosity (150° C.), cP	2.1	2.1	2.1	2.1	2.1	2.0	2.0
Noack Volatility, %	<15	<15	<15	<15	<15	<15	<15
P, wt. %	0.074	0.074	0.074	0.074	0.074	0.074	0.074
S, wt. %	0.18	0.18	0.19	0.21	0.29	0.18	0.18
Zn, wt. %	0.088	0.088	0.088	0.088	0.088	0.088	0.088
Ca, wt. %	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Mg, wt. %	0.051	0.051	0.051	0.051	0.051	0.051	0.051
B, wt. %	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Mo, wt. %	—	0.030	0.10	0.030	0.10	0.030	0.10
N, wt. %	0.09	0.11	0.14	0.10	0.11	0.10	0.13
Ca/Mg mass ratio	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Komatsu Hot Tube Test							
Merit Rating ^(a)	8.5	8.5	6.5	8.5	7.0	8.5	6.0
SRV Friction Test							
Coefficient of Friction	0.17	0.062	0.048	0.057	0.052	0.079	0.059
Shell 4 Ball Wear Test							
Wear Scar Diameter, mm	0.41	0.39	0.39	0.42	0.39	0.44	0.30

^(a)Merit rating >7 (Good); Merit Rating = 6-7 (Marginally Acceptable); and Merit Rating <6 (Poor)

1. A lubricating oil composition having a HTHS viscosity at 150° C. in a range of about 1.3 to about 2.3 cP, comprising:

- (a) a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100° C. in a range of 1.5 to 6.0 mm²/s; and
- (b) a molybdenum-succinimide complex providing 200 to 1500 ppm by weight of molybdenum to the lubricating oil composition, wherein the molybdenum-succinimide complex is the only source of molybdenum in the lubricating oil composition; and

further wherein the lubricating oil composition is a 0W-8, 0W-12 or 0W-16 SAE viscosity grade.

2. (canceled)

3. The lubricating oil composition of claim 1, wherein the oil of lubricating viscosity is a base oil selected from one or more of API Group II, Group III, Group IV, and Group V.

4. The lubricating oil composition of claim 1, wherein the succinimide is a C₂₄ to C₃₅₀ alkyl or alkenyl succinimide.

5. The lubricating oil composition of claim 1, wherein the succinimide is a polyisobutenyl succinimide and the polyisobutenyl succinimide is a reaction product of a C₇₀ to C₁₂₈ polyisobutenyl succinic anhydride and a polyalkylene polyamine selected from triethylenetetramine, tetraethylene-pentamine, and combinations thereof.

6. The lubricating oil composition of claim 1, wherein the molybdenum-succinimide complex is a sulfurized molybdenum-succinimide complex.

7. The lubricating oil composition of claim 1, wherein the molybdenum-succinimide complex is an unsulfurized molybdenum-succinimide complex.

8. The lubricating oil composition of claim 1, which is for an internal combustion engine selected from a direct injection spark ignition engine and a port fuel injection spark ignition engine coupled to an electric motor/battery system in a hybrid vehicle.

9. A method of reducing friction in an engine lubricated with a lubricant by using as the lubricant the lubricating oil composition of claim 1.

10. A method of reducing wear in an engine lubricated with a lubricant by using as the lubricant the lubricating oil composition of claim 1.

11. A method of improving fuel economy in an engine lubricated with a lubricant by using as the lubricant the lubricating oil composition of claim 1.

12. The method of any one of claims 9, 10, and 11, in which the engine is a direct injection spark ignition engine.

13. The method of any one of claims 9, 10, and 11, in which engine is a port fuel injection spark ignition engine coupled to an electric motor/battery system in a hybrid vehicle.

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