(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 882 330 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
22.09.2021 Bulletin 2021/38

(51) Int Cl.:
C10M 169/04 *(2006.01)*

(21) Application number: **21163719.4**

(22) Date of filing: **19.03.2021**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **20.03.2020 US 202062992210 P**

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(54) **LOW VISCOSITY LUBRICATING OIL COMPOSITION**

(57) The present invention generally relates to lubricating oil compositions useful for reducing NOACK volatility in finished lubricating oils of an internal combustion engine. Also disclosed is a method for reducing NOACK volatility in finished lubricating oils in said engine.

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Description

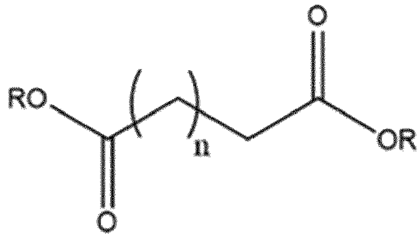
BACKGROUND OF THE DISCLOSURE

[0001] The lubricant industry is actively engaged in research related to improving fuel economy. One well-known way of increasing fuel economy is to decrease the viscosity of lubricating oils. Engine oils that demonstrate excellent fuel economy performance are usually formulated to be low viscosity oils. Viscosity index improvers (VII) are often used to reduce fluid friction from viscosity resistance under low temperature. A disadvantage of low viscosity engine oils is that they can have high volatility which leads to high evaporation loss (meaning an increase in oil consumption).

[0002] Attempts to overcome the above problems include formulating with low volatility base oils such as esters and poly-α-olefins. However, these base oils may not be ideal for low viscosity engine oils such as OW-12, 0W-8, and 0W-4.

SUMMARY OF THE DISCLOSURE

[0003] In accordance with one embodiment of the present invention, provided is a lubricating oil composition comprising: a. a base oil comprising a diester having one of the following structures:



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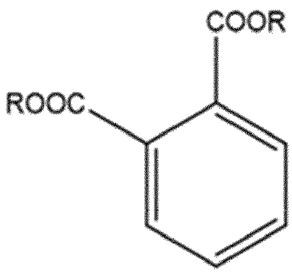
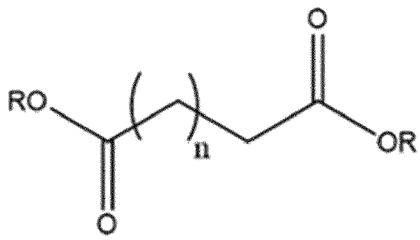


(II),

wherein each R is independently a C_1-C_{20} saturated or unsaturated alky group, and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and 75-500 ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersants.

[0004] In accordance with another embodiment of the present invention, provided is a method of reducing evaporation loss in an internal combustion engine comprising lubricating said engine with a lubricating oil composition comprising: a base oil comprising a diester having one of the following structures:



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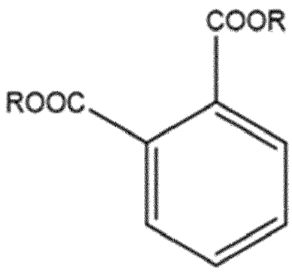
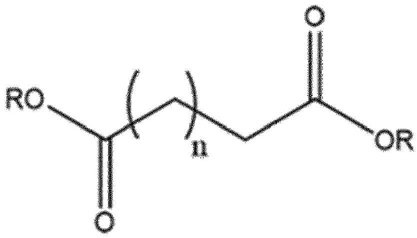


(II),

wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and 75 to 500 ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersant.

[0005] In accordance with yet another embodiment of the present invention, provided is a method of improving fuel efficiency of an engine comprising lubricating the engine with a lubricating oil composition comprising: a base oil comprising a diester having one of the following structures:



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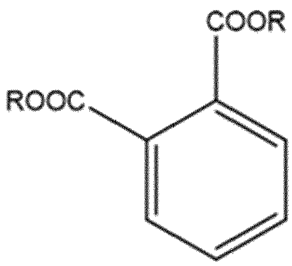


(II),

wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and 75 to 500 ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersant.

DETAILED DESCRIPTION OF THE DISLCOSURE

[0006] While the disclosure is susceptible to various modifications and alternative forms, specific embodiments thereof are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the appended claims.

[0007] To facilitate the understanding of the subject matter disclosed herein, a number of terms, abbreviations or other shorthand as used herein are defined below. Any term, abbreviation or shorthand not defined is understood to have the ordinary meaning used by a skilled artisan contemporaneous with the submission of this application.

DEFINITIONS

[0008] As used herein, the following terms have the following meanings, unless expressly stated to the contrary. In this specification, the following words and expressions, if and when used, have the meanings given below.

[0009] A "major amount" means in excess of 50 weight % of a composition.

[0010] 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.

[0011] "Active ingredients" or "actives" or "oil free" refers to additive material that is not diluent or solvent.

[0012] All percentages reported are weight % on an active ingredient basis (i.e., without regard to carrier or diluent oil) unless otherwise stated.

[0013] The abbreviation "ppm" means parts per million by weight, based on the total weight of the lubricating oil composition.

[0014] High temperature high shear (HTHS) viscosity at 150°C was determined in accordance with ASTM D4683.

[0015] Kinematic viscosity at 100°C (KV_{100}) was determined in accordance with ASTM D445.

[0016] Metal - The term "metal" refers to alkali metals, alkaline earth metals, or mixtures thereof.

[0017] The term "oil soluble" or "dispersible" is used to convey that the amount needed to provide the desired level of activity or performance can be incorporated by being dissolved, dispersed or suspended in an oil of lubricating viscosity. Usually, this means that at least about 0.001% by weight of the material can be incorporated in a lubricating oil composition. For a further discussion of the terms oil soluble and dispersible, particularly "stably dispersible", see U.S. Pat. No. 4,320,019 which is expressly incorporated herein by reference for relevant teachings in this regard.

[0018] The term "sulfated ash" as used herein refers to the non-combustible residue resulting from detergents and metallic additives in lubricating oil. Sulfated ash may be determined using ASTM Test D874.

[0019] The term "Total Base Number" or "TBN" as used herein refers to the amount of base equivalent to milligrams of KOH in one gram of sample. Thus, higher TBN numbers reflect more alkaline products, and therefore a greater alkalinity. TBN was determined using ASTM D 2896 test.

[0020] Boron, calcium, magnesium, molybdenum, phosphorus, sulfur, and zinc contents were determined in accordance with ASTM D5185.

[0021] Nitrogen content was determined in accordance with ASTM D4629.

[0022] NOACK volatility was determined by any one of ASTM D5800A-D or ASTM D6417.

[0023] Unless otherwise specified, all percentages are in weight percent.

[0024] While the disclosure is susceptible to various modifications and alternative forms, specific embodiments thereof are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the appended claims.

[0025] Note that not all of the activities described in the general description or the examples are required, that a portion of a specific activity may not be required, and that one or more further activities may be performed in addition to those described. Still further, the order in which activities are listed is not necessarily the order in which they are performed.

[0026] Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. However, the benefits, advantages, solutions to problems, and any feature(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature of any or all the claims.

[0027] The specification and illustrations of the embodiments described herein are intended to provide a general understanding of the structure of the various embodiments.

[0028] As used herein, the terms "comprises," "comprising," "includes," "including," "has," "having," or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of features is not necessarily limited only to those features but may include other features not expressly listed or other features that are inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, "or" refers to an inclusive-or and not to an exclusive-or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

[0029] The use of "a" or "an" is employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the embodiments of the disclosure. This description should be read to include one or at least one and the singular also includes the plural, or vice versa, unless it is clear that it is meant otherwise. The term "averaged," when referring to a value, is intended to mean an average, a geometric mean, or a median value. Group numbers corresponding to columns within the Periodic Table of the elements use the "New Notation" convention as seen in the CRC Handbook of Chemistry and Physics, 81st Edition (2000-2001).

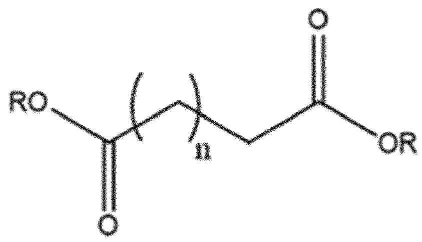
[0030] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. The materials, methods, and examples are illustrative only and not intended to be limiting. To the extent not described herein, many details regarding specific materials and processing acts are conventional and may be found in textbooks and other sources within the lubricants as well as the oil and gas industries.

[0031] The specification and illustrations are not intended to serve as an exhaustive and comprehensive description of all the elements and features of formulations, compositions, apparatus and systems that use the structures or methods described herein. Separate embodiments may also be provided in combination in a single embodiment, and conversely, various features that are, for brevity, described in the context of a single embodiment, may also be provided separately or in any sub-combination. Further, reference to values stated in ranges includes each and every value within that range. Many other embodiments may be apparent to skilled artisans only after reading this specification. Other embodiments may be used and derived from the disclosure, such that a structural substitution, logical substitution, or another change may be made without departing from the scope of the disclosure. Accordingly, the disclosure is to be regarded as illustrative rather than restrictive.

[0032] It has been discovered that a lubricating oil composition containing diester base oil and borated dispersant results in lower NOACK volatility without increasing the viscosity of the oil. This, in turn, reduces evaporation loss compared to other lubricating oil compositions that are formulated to have low viscosity.

[0033] This disclosure provides a lubricating oil composition comprising:

a. a base oil comprising a diester having one of the following structures:



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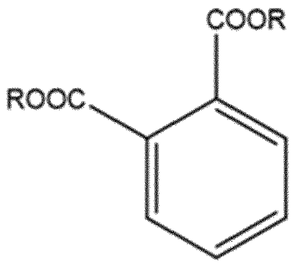

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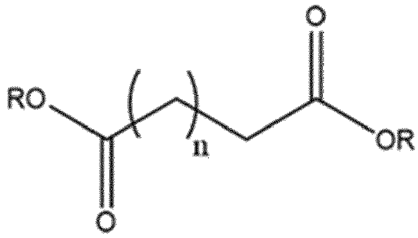
wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270;

b. 75 to 500 ppm of boron, based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or moreboron-containing dispersant.

[0034] Further disclosed is a method of reducing evaporation loss or improving fuel efficiency in an internal combustion engine comprising lubricating said engine with a lubricating oil composition comprising:

a. a base oil comprising a diester having one of the following structures:



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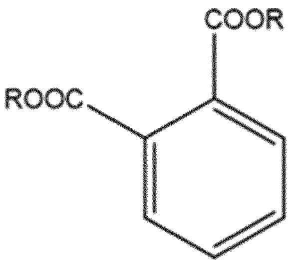


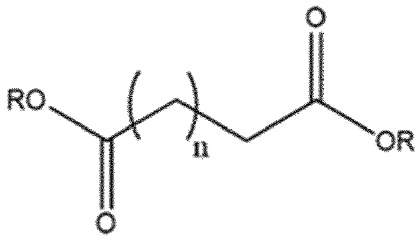
(II),

wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and

b. from 75 to 500 ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersants.

[0035] Also disclosed is the use of a lubricating oil composition to reduce evaporation loss or improve fuel efficiency in an internal combustion engine wherein the lubricating oil composition comprises:

a. a base oil comprising a diester having one of the following structures:



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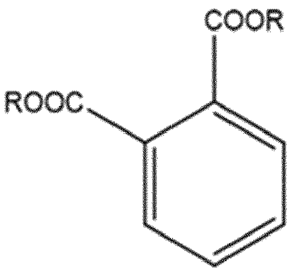


(II),

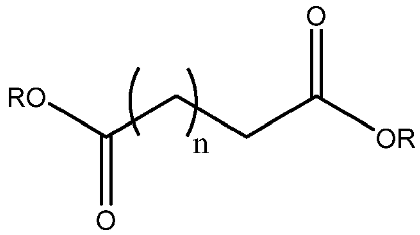
wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and
b. from 75 to 500 ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersants.

[0036] The lubricating oil composition of the present invention include components that work synergistically to lower NOACK volatility of the lubricating oil while maintaining low viscosity. These components may be particularly useful for formulating lubricating oils that exhibit desirable properties such as improved fuel efficiency in engines.

Base Oils

[0037] In one aspect, the disclosure provides one or more base oils. The one or more base oils includes one or more diester base oil and optionally, an additional base oil. The total amount of the one or more base oils is about 50 to about 99 wt.% based on the finished lubricant.

[0038] In one embodiment, the diester has one of the following structures:



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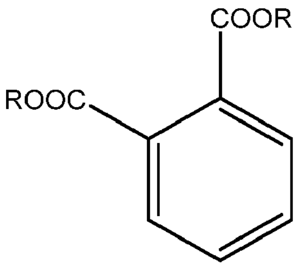


(2),

where each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8. In one embodiment, each R is independently selected from the group consisting of C_1-C_{18} saturated or unsaturated alky group. In one embodiment, each R is independently selected from the group consisting of C_1-C_{16} saturated or unsaturated alky group. In one embodiment, each R is independently selected from the group consisting of C_1-C_{14} saturated or unsaturated alky group. In one embodiment, each R is independently selected from the group consisting of C_1-C_{12} saturated or unsaturated alky group.

[0039] In one embodiment, the disclosure provides a diester base oil in an amount of from 5 to 99 wt.%, 25 to 99 wt.%, 50 to 99 wt.%, from 55 to 99 wt.%, from 60 to 99 wt.%, from 65 to 99 wt.%, from 70 to 99 wt.%, from 75 to 99 wt.%, from 80 to 99 wt.%. based on the finished lubricant.

[0040] Typically, the diester will have a kinematic viscosity at 100 °C of from 2.5 to 3.5mm^2/s according to ASTM D445.

[0041] Typically, the diester will have a viscosity index of from 110 to 175 according to ASTM D2270. In one embodiment, the diester has a viscosity index of from 125 to 175, from 135 to 175 according to ASTM D2270.

Boron-Containing Dispersant

[0042] Examples of boron containing dispersants include borated ashless dispersants such as borated polyalkenyl succinic anhydrides; borated non-nitrogen containing derivatives of a polyalkylene succinic anhydride; borated basic nitrogen compounds selected from the group consisting of succinimides, carboxylic acid amides, hydrocarbyl monoamines, hydrocarbyl polyamines, Mannich bases, phosphonoamides, thiophosphonamides and phosphoramides, thiazoles (e.g., 2,5-dimercapto-1,3,4-thiadiazoles, mercaptobenzothiazoles and derivatives thereof), triazoles (e.g., alkyltriazoles and benzotriazoles), copolymers which contain a carboxylate ester with one or more additional polar function, including amine, amide, imine, imide, hydroxyl, carboxyl, and the like (e.g., products prepared by copolymerization of long chain alkyl acrylates or methacrylates with monomers of the above function); and the like and combinations thereof. A preferred borated dispersant is a succinimide derivative of boron such as, for example, a borated polyisobutenyl succinimide.

[0043] Examples of borated ashless dispersants are the borated ashless hydrocarbyl succinimide dispersants prepared by reacting a hydrocarbyl succinic acid or anhydride with an amine. Preferred hydrocarbyl succinic acids or anhydrides are those where the hydrocarbyl group is derived from a polymer of a C_3 or C_4 monoolefin, especially a polyisobutylene wherein the polyisobutenyl group has a number average molecular weight (Mn) of from 700 to 5,000, more preferably from 900 to 2,500. Such dispersants generally have at least 1, preferably 1 to 2, more preferably 1.1 to 1.8, succinic groups for each polyisobutenyl group. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant, is derived from a polyisobutylene group having a number average molecular weight of from about 550 to about 5000. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant, is derived from a polyisobutylene group having a number average molecular weight of from about 550 to about 4000. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant, is derived from a polyisobutylene group having a number average molecular weight of from about 550 to about 3000. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant is derived from a polyisobutylene group having a number average molecular weight of greater than 550 to about 2300. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant, is derived from a polyisobutylene group having a number average molecular weight of from about 950 to about 2300. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant, is derived from a polyisobutylene group having a number average molecular weight of from about 950 to about 1300. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant is derived from a polyisobutylene group having a number average molecular weight of about 2300. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant is derived from a polyisobutylene group having a number average molecular weight of about 1300. In one embodiment, the oil soluble or oil dispersible borated polyisobutylene succinimide dispersant, is derived from a polyisobutylene group having a number average molecular weight of about 1000.

[0044] Preferred amines for reaction to form the succinimide are polyamines having from 2 to 60 carbon atoms and from 2 to 12 nitrogen atoms per molecule, and particularly preferred are the polyalkyleneamines represented by the Structure (3):

$$NH_2(CH_2)_n\text{-}(NH(CH_2)_n)_m\text{-}NH_2 \qquad \text{Structure (3)}$$

wherein n is 2 to 3 and m is 0 to 10. Illustrative are ethylene diamine, diethylene triamine, triethylene tetramine, tetraethylene pentamine, tetrapropylene pentamine, pentaethylene hexamine and the like, as well as the commercially available mixtures of such polyamines. Amines including other groups such as hydroxy, alkoxy, amide, nitride and imidazoline groups may also be used, as may polyoxyalkylene polyamines. The amines are reacted with the alkenyl succinic acid or anhydride in conventional ratios of about 1:1 to 10:1, preferably 1:1 to 3:1, moles of alkenyl succinic acid or anhydride to polyamine, and preferably in a ratio of about 1:1, typically by heating the reactants to from 100° to 250° C., preferably 125° to 175°C. for 1 to 10, preferably 2 to 6, hours.

[0045] The boration of alkenyl succinimide dispersants is also well known in the art as disclosed in U.S. Pat. Nos. 3,087,936 and 3,254,025. The succinimide may for example be treated with a boron compound selected from the group consisting of boron, boron oxides, boron halides, boron acids and esters thereof, in an amount to provide from 0.1 atomic proportion of boron to 10 atomic proportions of boron for each atomic proportion of nitrogen in the dispersant.

[0046] The borated product will generally contain 0.1 to 2.0, preferably 0.2 to 0.8 weight percent boron based upon the total weight of the borated dispersant. Boron is considered to be present as dehydrated boric acid polymers attaching at the metaborate salt of the imide. The boration reaction is readily carried out adding from 1 to 3 weight percent (based on the weight of dispersant) of said boron compound, preferably boric acid, to the dispersant as a slurry in mineral oil and heating with stirring from 135 °C to 165 °C for 1 to 5 hours followed by nitrogen stripping filtration of the product. Alternatively, boric acid may be added to the hot reaction mixture of succinic acid or anhydride and amine while removing water.

[0047] The boron-containing dispersant is present in an amount sufficient to provide from 100 to 1000, from 100 to 900, from 100 to 800, from 100 to 700 ppm of boron based on the total weight of the lubricating oil composition.

Other Dispersants

[0048] 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 effective to reduce formation of deposits upon use in gasoline and diesel engines.

[0049] 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.

[0050] 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.

[0051] As is known in the art, the dispersants may be post-treated (e.g., with a boronating agent or a cyclic carbonate).

[0052] 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.

[0053] Dispersants may be present at 0.1 to 10 wt. % (e.g., 0.5 to 8, 0.7 to 7, 0.7 to 6, 0.7 to 6, 0.7 to 5, 0.7 to 4 wt. %), based on an actives level, of the lubricating oil composition.

[0054] Nitrogen from the dispersants is present from greater than 0.0050 to 0.30 wt.% (e.g., greater than 0.0050 to 0.10 wt.%, 0.0050 to 0.080 wt.%, 0.0050 to 0.060 wt. %, 0.0050 to 0.050 wt.%, 0.0050 to 0.040 wt.%, 0.0050 to 0.030 wt.%,) based on the weight of the dispersants in the finished oil.

Detergents

[0055] Detergents that may be used include oil-soluble overbased sulfonate, non-sulfur containing phenate, sulfurized phenates, salixarate, salicylate, saligenin, complex detergents and naphthenate detergents and other oil-soluble alkylhydroxybenzoates of a metal, particularly the alkali or alkaline earth metals, e.g., barium, sodium, potassium, lithium, calcium, and magnesium. The most commonly used metals are calcium and magnesium, which may both be present in detergents used in a lubricant, and mixtures of calcium and/or magnesium with sodium.

[0056] Overbased metal detergents are generally produced by carbonating a mixture of hydrocarbons, detergent acid, for example: sulfonic acid, alkylhydroxybenzoate etc., metal oxide or hydroxides (for example calcium oxide or calcium hydroxide) and promoters such as xylene, methanol and water. For example, for preparing an overbased calcium sulfonate, in carbonation, the calcium oxide or hydroxide reacts with the gaseous carbon dioxide to form calcium carbonate. The sulfonic acid is neutralized with an excess of CaO or $Ca(OH)_2$, to form the sulfonate.

[0057] Overbased detergents may be low overbased, e.g., an overbased salt having a TBN below 100 on an actives basis. In one aspect, the TBN of a low overbased salt may be from about 30 to about 100. In another aspect, the TBN of a low overbased salt may be from about 30 to about 80. Overbased detergents may be medium overbased, e.g., an overbased salt having a TBN from about 100 to about 250 on an actives basis. In one aspect, the TBN of a medium overbased salt may be from about 100 to about 200. In another aspect, the TBN of a medium overbased salt may be from about 125 to about 175. Overbased detergents may be high overbased, e.g., an overbased salt having a TBN above 250 on an actives basis. In one aspect, the TBN of a high overbased salt may be from about 250 to about 800 on an actives basis.

[0058] In one aspect, the detergent can be one or more alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid. Suitable hydroxyaromatic compounds include mononuclear monohydroxy and polyhydroxy aromatic hydrocarbons having 1 to 4, and preferably 1 to 3, hydroxyl groups. Suitable hydroxyaromatic compounds include phenol, catechol, resorcinol, hydroquinone, pyrogallol, cresol, and the like.

[0059] Generally, the amount of the detergent can be from about 0.001 wt. % to about 50 wt. %, or from about 0.05 wt. % to about 25 wt. %, or from about 0.1 wt. % to about 20 wt. %, or from about 0.01 to 15 wt. % based on the total weight of the lubricating oil composition.

Antiwear Agents

[0060] The lubricating oil composition disclosed herein can comprise one or more antiwear agent. Antiwear agents reduce wear of metal parts. Suitable anti-wear agents include dihydrocarbyl dithiophosphate metal salts such as zinc dihydrocarbyl dithiophosphates (ZDDP) of the following Structure 8:

$$Zn[S\text{-}P(=S)(OR^1)(OR^2)]_2 \qquad (8),$$

wherein R^1 and R^2 may be the same of 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., R^1+R^2) will be at least 5. The zinc dihydrocarbyl dithiophosphate can therefore comprise zinc dialkyl dithiophosphates. The zinc dialkyl dithiophosphate is a primary, secondary zinc dialkyl dithiophosphate, or a combination thereof. 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. In one embodiment, the lubricating oil composition containing the magnesium salicylate detergent described herein further comprises an antioxidant compound. In one embodiment, the antioxidant is a diphenylamine antioxidant. In another embodiment, the antioxidant is a hindered phenol antioxidant. In yet another embodiment, the antioxidant is a combination of a diphenylamine antioxidant and a hindered phenol antioxidant.

Antioxidants

[0061] The lubricating oil composition disclosed herein can comprise one or more antioxidant. 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.

[0062] 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).

[0063] 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'-dioctyldiphenylamine, 4,4'-dinonyldiphenylamine, *N*-phenyl-1-naphthylamine, *N*-(4-*tert*-octyphenyl)-1-naphthylamine, and *N*-(4-octylphenyl)-1-naphthylamine. Antioxidants may be present at 0.01 to 5 wt. % (e.g., 0.1 to 2 wt. %) of the lubricating oil composition.

Foam Inhibitors

[0064] The lubricating oil composition disclosed herein can comprise one or more foam inhibitor that can break up foams in oils. Non-limiting examples of suitable foam inhibitors or anti-foam inhibitors include silicone oils or polydimethylsiloxanes, fluorosilicones, alkoxylated aliphatic acids, polyethers (e.g., polyethylene glycols), branched polyvinyl ethers, alkyl acrylate polymers, alkyl methacrylate polymers, polyalkoxyamines and combinations thereof.

Additional Co-Additives

[0065] The lubricating oil compositions of the present disclosure may also contain other conventional additives that can impart or improve any desirable property of the lubricating oil composition in which these additives are dispersed or dissolved. Any additive known to a person of ordinary skill in the art may be used in the lubricating oil compositions disclosed herein. Some suitable additives have been described in Mortier et al., "Chemistry and Technology of Lubricants", 2nd Edition, London, Springer, (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications", New York, Marcel Dekker (2003), both of which are incorporated herein by reference. For example, the lubricating oil compositions can be blended with antioxidants, anti-wear agents, detergents such as metal detergents, rust inhibitors, dehazing agents, demulsifying agents, metal deactivating agents, friction modifiers, pour point depressants, antifoaming agents, co-solvents, corrosion-inhibitors, ashless dispersants, multifunctional agents, dyes, extreme pressure agents and the like and mixtures thereof. A variety of the additives are known and commercially available. These additives, or their analogous compounds, can be employed for the preparation of the lubricating oil compositions of the disclosure by the usual blending procedures.

[0066] In the preparation of lubricating oil formulations, it is common practice to introduce the additives in the form of 10 to 100 wt. % active ingredient concentrates in hydrocarbon oil, e.g. mineral lubricating oil, or other suitable solvent.

[0067] Usually these concentrates may be diluted with 3 to 100, e.g., 5 to 40, parts by weight of lubricating oil per part by weight of the additive package in forming finished lubricants, e.g. crankcase motor oils. The purpose of concentrates, of course, is to make the handling of the various materials less difficult and awkward as well as to facilitate solution or dispersion in the final blend.

[0068] Each of the foregoing additives, when used, is used at a functionally effective amount to impart the desired properties to the lubricant. Thus, for example, if an additive is a friction modifier, a functionally effective amount of this friction modifier would be an amount sufficient to impart the desired friction modifying characteristics to the lubricant.

[0069] In general, the concentration of each of the additives in the lubricating oil composition, when used, may range from about 0.001 wt. % to about 20 wt. %, from about 0.01 wt. % to about 15 wt. %, or from about 0.1 wt. % to about 10 wt. %, from about 0.005 wt.% to about 5 wt.%, or from about 0.1 wt.% to about 2.5 wt.%, based on the total weight of the lubricating oil composition. Further, the total amount of the additives in the lubricating oil composition may range from about 0.001 wt.% to about 20 wt.%, from about 0.01 wt.% to about 10 wt.%, or from about 0.1 wt.% to about 5 wt.%, based on the total weight of the lubricating oil composition.

Additional Base Oils of lubricating viscosity

[0070] 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.

[0071] 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.

[0072] 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.

[0073] The base oil may be derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are made from synthesis gas containing H_2 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.

[0074] The base oil may be derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are made from synthesis gas containing H_2 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.

[0075] 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.

[0076] 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.

[0077] 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

	Base Oil Properties		
Group [(a)]	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.
[(e)] 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.

[0078] The oil of lubricating viscosity for use in the lubricating oil compositions of this disclosure, also referred to as a base oil, is typically present in a major amount, e.g., an amount of greater than 50 wt. %, preferably greater than about 70 wt. %, more preferably from about 80 to about 99.5 wt. % and most preferably from about 85 to about 98 wt. %, based on the total weight of the composition. The expression "base oil" as used herein shall be understood to mean a base stock or blend of base stocks which is a lubricant component that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's location); that meets the same manufacturer's specification; and that is identified by a unique formula, product identification number, or both. The base oil for use herein can be any presently known or later-discovered oil of lubricating viscosity used in formulating lubricating oil compositions for any and all such applications, e.g., engine oils, marine cylinder oils, functional fluids such as hydraulic oils, gear oils, transmission fluids, etc. Additionally, the base oils for use herein can optionally contain viscosity index improvers, e.g., polymeric alkylmethacrylates; olefinic copolymers, e.g., an ethylene-propylene copolymer or a styrenebutadiene copolymer; and the like and mixtures thereof.

Finished Lubricant Properties

[0079] Typically, the kinematic viscosity at 100°C (according to ASTM D445) of the lubricating composition is at most 9.3 mm^2/s, preferably from 3.8 to 9.3 mm^2/s, from 3.8 to 8.2 mm^2/s, from 3.8 to 7.1 mm^2/s, from 3.8 to 6.1 mm^2/s.

[0080] Typically, the high temperature, high shear viscosity ("HTHS") at 150 °C (according to ASTM D4683) of the lubricating composition is in the range of from 1.3 to 2.6 mPa·s, from 1.3 to 2.4 mPa·s, from 1.3 to 2.2 mPa·s, from 1.3 to 2.0 mPa·s, from 1.3 to 1.8 mPa·s,

[0081] Typically, the high temperature, high shear viscosity ("HTHS") at 80 °C of the lubricating composition is less than 4.5 mPa·s.

[0082] Typically, the NOACK volatility (according to ASTM D5800B) of the lubricating composition is 22.0 wt. % or below, 21.0 wt. % or below, 20.0 wt. % or below, 19.0 wt. % or below, 18.0 wt. % or below, 17.0 wt. % or below, 16.0 wt. % or below, 15.0 wt. % or below, 14.5 wt. % or below, 14.0 wt. % or below, 13.5 wt. % or below, 13.0 wt. % or below, 12.5 wt. % or below, 12.0 wt. % or below, 11.5 wt. % or below, 11.0 wt. % or below. 10.5 wt. % or below, 10.0 wt. % or below. Typically, the NOACK volatility is at least 4.0 wt. %. In other embodiments the NOACK volatility is from 15.0 to 2.0, from 15.0 to 3.0, from 14.5 to 5.0, from 14.5 to 7.0, from 14.5 to 8.0, from 14.5 to 9.0 wt. %.

[0083] The following examples are presented to exemplify embodiments of the disclosure but are not intended to limit the disclosure to the specific embodiments set forth. Unless indicated to the contrary, all parts and percentages are by weight. All numerical values are approximate. When numerical ranges are given, it should be understood that embodiments outside the stated ranges may still fall within the scope of the disclosure. Specific details described in each example should not be construed as necessary features of the disclosure.

[0084] It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. For example, the functions described above and implemented as the best mode for operating the present disclosure are for illustration purposes only. Other arrangements and methods may be implemented by those skilled in the art without departing from the scope and spirit of this disclosure. Moreover, those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

EXAMPLES

[0085] The following examples are intended for illustrative purposes only and do not limit in any way the scope of the present disclosure.

COMPARATIVE EXAMPLE 1

[0086] A lubricating oil composition was prepared by adding 100 wt. % of Bis-2-ethylhexyl azelate base oil. The formulation had a NOACK of 21.7 % and HTHS 80 of 3.61 mPa·s.

COMPARATIVE EXAMPLE 2

[0087] A lubricating oil composition was prepared by adding 97 wt. % of UNISTER® M-480R (NOF CORPORATION, 2 cSt) and 3 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.019 wt.% of boron. The formulation had a NOACK of 34.3 % and HTHS 80 of 2.60 mPa·s.

COMPARATIVE EXAMPLE 3

[0088] A lubricating oil composition was prepared by adding 99 wt. % of Bis-2-ethylhexyl azelate and 0.79 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.005 wt.% of boron. The formulation had a NOACK of 21.4 % and HTHS 80 of 3.87 mPa·s.

COMPARATIVE EXAMPLE 4

[0089] A lubricating oil composition was prepared by adding 97 wt. % of Group II base oil (KV 100 = 3.05, VI = 106) and 3 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.019 wt.% of boron. The formulation had a NOACK of 36.0 % and HTHS 80 of 3.94 mPa·s.

COMPARATIVE EXAMPLE 5

[0090] A lubricating oil composition was prepared by adding 97 wt. % of Group III base oil (KV 100 = 4.19, VI = 125)and 3 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.019 wt.% of boron. The formulation had a NOACK of 13.0 % and HTHS 80 of 5.62 mPa·s.

COMPARATIVE EXAMPLE 6

[0091] A lubricating oil composition was prepared by adding 97 wt. % of Di-isotridecyl adipate (5 cSt) and 3 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.019 wt.% of boron. The formulation had a NOACK of 3.10 % and HTHS 80 of 7.26 mPa·s.

COMPARATIVE EXAMPLE 7

[0092] A lubricating oil composition was prepared by adding 99 wt. % of Bis-2-ethylhexyl azelate and 0.37 wt.% based on the concentrate of a HOB borated sulfonate detergent providing the finished oil with approximately 0.015 wt.% of boron. The formulation had a NOACK of 21.0 % and HTHS 80 of 3.71 mPa·s.

COMPARATIVE EXAMPLE 8

[0093] A lubricating oil composition was prepared by adding 99 wt. % of Bis-2-ethylhexyl azelate and 0.22 wt.% based on the concentrate of a potassium borate dispersion providing the finished oil with approximately 0.015 wt.% of boron. The formulation had a NOACK of 20.8 % and HTHS 80 of 3.58 mPa·s.

COMPARATIVE EXAMPLE 9

[0094] A lubricating oil composition was prepared by adding 99 wt. % of Bis-2-ethylhexyl azelate and 0.62 wt.% based on the concentrate of a borated glycerol monooleate friction modifier providing the finished oil with approximately 0.015 wt.% of boron. The formulation had a NOACK of 20.6 % and HTHS 80 of 3.59 mPa·s.

EXAMPLE 1

[0095] A lubricating oil composition was prepared by adding 98 wt. % of Bis-2-ethylhexyl azelate base oil and 1.59 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.008 wt.% of boron. The formulation had a NOACK of 17.7 % and HTHS 80 of 3.73 mPa·s.

EXAMPLE 2

[0096] A lubricating oil composition was prepared by adding 97 wt. % of Bis-2-ethylhexyl azelate base oil and 3 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.019 wt.% of boron.

The formulation had a NOACK of 16.4 % and HTHS 80 of 4.01 mPa·s.

EXAMPLE 3

[0097] A lubricating oil composition was prepared by adding 48 wt. % of Bis-2-ethylhexyl azelate base oil, 48 wt. % of Group III base oil (KV 100 = 4.19, VI = 125)and 3 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.019 wt.% of boron. The formulation had a NOACK of 15.9 % and HTHS 80 of 4.50 mPa·s.

EXAMPLE 4

[0098] A lubricating oil composition was prepared by adding 98 wt. % of Bis-2-ethylhexyl azelate and 2.38 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.015 wt.% of boron. The formulation had a NOACK of 16.7 % and HTHS 80 of 4.05 mPa·s.

EXAMPLE 5

[0099] A lubricating oil composition was prepared by adding 96 wt. % of Bis-2-ethylhexyl azelate and 3.97 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1300 providing the finished oil with approximately 0.025 wt.% of boron. The formulation had a NOACK of 15.9 % and HTHS 80 of 4.30 mPa·s.

EXAMPLE 6

[0100] A lubricating oil composition was prepared by adding 96 wt. % of Bis-2-ethylhexyl azelate and 3 wt.% based on the concentrate of a borated polyisobutenyl bis-succcinimide dispersant where the number average molecular weight of the polyisobutene is approximately 1000 providing the finished oil with approximately 0.018 wt.% of boron. The formulation had a NOACK of 15.0 % and HTHS 80 of 3.85 mPa·s.

TABLE 1.

	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Comp. Ex. 6	Comp. Ex. 7	Comp. Ex. 8	Comp. Ex. 9
Boron Additive (wt%)									
Borated Succinimide (1300MW PIB)		3.0	0.8	3.0	3.0	3.0			
Borated Succinimide (1000MW PIB)									
Borated Sulfonate							0.37		
Potassium Borate Dispersion								0.22	
Borated glycerol monooleate									0.62
Base oil Ratio (%)									
Group II				100					
Group III					100				
UNISTER M-480R (Monoester)		100							
Di-isotridecyl adipate (KV100=5 CSt)						100			
Bis-2-ethylhexyl azelate (KV100=3.0 CSt)	100		100				100	100	100
Finished Oil properties									
Total Boron Content (ppm)	0	190	50	190	190	190	150	150	150
HTHS @ 80°C (mPas)	**3.61**	**2.60**	**3.87**	**3.94**	**5.62**	**7.26**	**3.71**	**3.58**	**3.59**
NOACK Volatility (%)	**21.7**	**34.3**	**21.4**	**36.0**	**13.0**	**3.1**	**21.0**	**20.8**	**20.6**

TABLE 1 (cont.)

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
Boron Additive (wt%)						
Borated Succinimide (1300MW PIB)	1.59	3.0	3.0	2.38	3.97	
Borated Succinimide (1000MW PIB)						3.0
Borated Sulfonate						
Potassium Borate Dispersion						
Borated glycerol monooleate						
Base oil Ratio (%)						
Group II						
Group III			50			
UNISTER M-480R (Monoester)						
Di-isotridecyl adipate (KV100=5 CSt)						
Bis-2-ethylhexyl azelate (KV100=3.0 CSt)	100	100	50	100	100	100
Finished Oil properties						
Total Boron Content (ppm)	80	190	190	150	250	180
HTHS @ 80°C	**3.73**	**4.01**	**4.50**	**4.05**	**4.30**	**3.85**
NOACK Volatility (%)	**17.7**	**16.4**	**15.9**	**16.7**	**15.9**	**15.0**

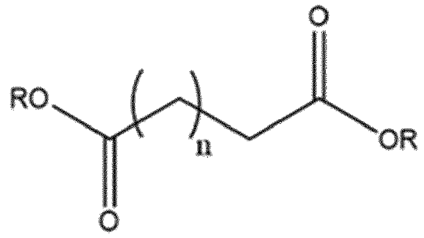
[0101] The viscometric property and NOACK volatility performance of the lubricating oils are shown in Table 1. The inventive examples demonstrate synergy from the combination of borated dispersants and low viscosity diester base oil (Bis-2-ethylhexyl azelate) that result in low NOACK volatility while maintaining low HTHS80. Inventive example 3 demonstrates that mixtures of diester base oil and conventional base oil also perform well.

[0102] In contrast, comparative examples 2 and 4 show that monoester base oils or conventional base oils alone do not perform nearly as well in the NOACK test. While higher viscosity base oils such as those used in comparative examples 5 and 6 yield low NOACK volatility, the resulting HTHS80 is undesirably high for fuel economy benefits. Comparative examples 7-9 also demonstrate that boron sources other than borated dispersants are not as effective in lowering the NOACK volatility.

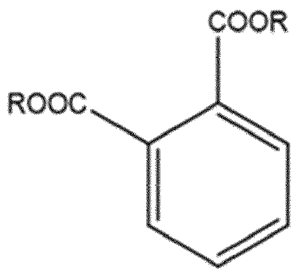
Claims

1. A lubricating oil composition comprising:

    a. a base oil comprising a diester having one of the following structures:



(I)



(II),

    wherein each R is independently a C_1-C_{20} saturated or unsaturated alky group, and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and

    b. 75-500ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersants.

2. The lubricating oil composition of claim 1, wherein the high shear viscosity at 80 °C of the lubricating composition is less than 4.5 mPa·s.

3. The lubricating oil composition of claim 1 or 2, further comprising:
detergent, anti-wear agent, antioxidant, foam inhibitor, rust inhibitor, dehazing agent, demulsifying agent, metal deactivating agent, friction modifier, pour point depressant, co-solvent, corrosion-inhibitor, ashless dispersant, multifunctional agent, dye, or extreme pressure agent.

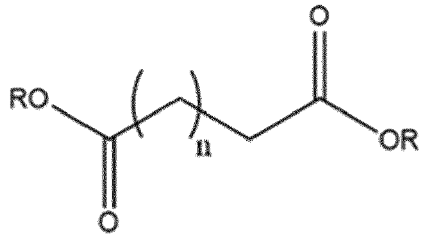
4. The lubricating oil composition of claim 1, 2 or 3, wherein the boron-containing dispersant is borated polyisobutenyl succinimide or borated polyalkenyl succinic anhydride.

5. The lubricating oil composition of claim 1, 2, 3 or 4, further comprising an additional base oil.

6. A method of reducing evaporation loss in an internal combustion engine comprising lubricating said engine with a

lubricating oil composition comprising:

a. a base oil comprising a diester having one of the following structures:



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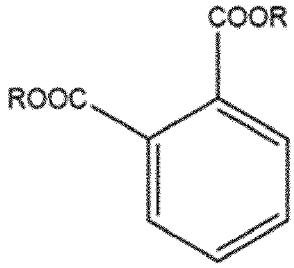
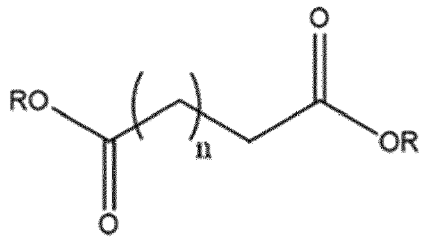


(II),

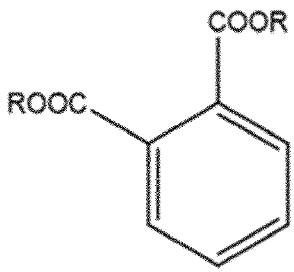
wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and
b. 75 to 500 ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersant.

7. A method of improving fuel efficiency of an engine, wherein the method comprises lubricating the engine with a lubricating oil composition comprising:

a. a base oil comprising a diester having one of the following structures:



(I)



(II),

wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky

group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270; and
b. 75 to 500 ppm of boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersant.

8. The method of claim 6 or 7, wherein the high shear viscosity at 80 °C of the lubricating composition is less than 4.5 mPa·s.

9. The method of claim 6, 7 or 8, wherein the lubricating oil composition further comprises: detergent, anti-wear agent, antioxidant, foam inhibitor, rust inhibitor, dehazing agent, demulsifying agent, metal deactivating agent, friction modifier, pour point depressant, co-solvent, corrosion-inhibitor, ashless dispersant, multifunctional agent, dye, or extreme pressure agent.

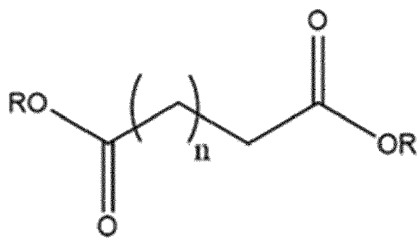
10. The method of claim 6, 7, 8 or 9, wherein the boron-containing dispersant is borated polyisobutenyl succinimide or borated polyalkenyl succinic anhydride.

11. The method of claim 6, 7, 8, 9 or 10, wherein the lubricating oil composition further comprises an additional base oil.

12. Use of a lubricating oil composition according to any one of claims 1-5 in an internal combustion engine to reduce evaporation loss in said engine.

13. Use of a lubricating oil composition according to any one of claims 1-5 in an engine to improve the fuel efficiency of said engine.

14. Use, in a lubricating oil composition, of 75 to 500 ppm boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersant, wherein the lubricating oil composition comprises a base oil comprising a diester having one of the following structures:



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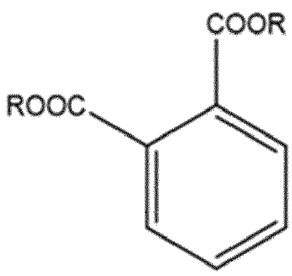
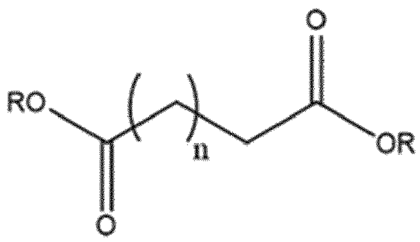


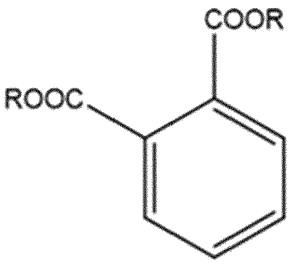
(II),

wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270, to reduce evaporation loss in an internal combustion engine lubricated with said lubricating oil composition.

15. Use, in a lubricating oil composition, of 75 to 500 ppm boron based on the entire weight of the lubricating oil composition, wherein the boron is provided by one or more boron-containing dispersant, wherein the lubricating oil composition comprises a base oil comprising a diester having one of the following structures:



(I)



(II),

wherein each R is independently selected from the group consisting of C_1-C_{20} saturated or unsaturated alky group and n is an integer from 1 to 8, wherein the diester has a kinematic viscosity at 100 °C of from 2.5 to 3.5 mm^2/s according to ASTM D445 and a viscosity index of from 110 to 175 according to ASTM D2270, to improve fuel efficiency of an engine lubricated with said lubricating oil composition.

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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 3719

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2016/257905 A1 (KOMATSUBARA HITOSHI [JP] ET AL) 8 September 2016 (2016-09-08) * paragraphs [0084], [0093]; table 1 * -----	1-5	INV. C10M169/04
X A	WO 2017/116897 A1 (EXXONMOBIL RES & ENG CO [US]) 6 July 2017 (2017-07-06) * paragraphs [0119], [0120]; claims 1,6; figure 1 * -----	1-11 12-15	
X A	US 2018/258366 A1 (OHKUBO HITOSHI [JP] ET AL) 13 September 2018 (2018-09-13) * paragraphs [0001], [2861], [0062]; example 15 * -----	1-11 12-15	

TECHNICAL FIELDS SEARCHED (IPC)

C10M
C10N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	28 July 2021	Klaes, Daphne

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