

LUBRICATING OIL COMPOSITION

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CROSS-REFERENCE TO RELATED APPICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/302,687 filed on January 25, 2022, which is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] This disclosure relates to lubricating oil compositions for automatic transmissions and/or continuously variable transmissions.

BACKGROUND

[0003] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0004] Lubricating oil compositions for automatic transmissions, referred to as automatic transmission fluids, have been used conventionally to assist smooth operation of automatic transmissions, which are installed in automobiles and include a torque converter, a gear mechanism, a wet clutch, and a hydraulic mechanism.

[0005] Generally, additives of lubricating oil compositions impact the friction properties of the wet clutch and steel plates. Additive effects are caused by both their physical and chemical absorption on the clutch materials, e.g., cellulose, aramid fibers, silica and steel plate surface. There has been an industry drive to change from cellulose rich to aramid rich wet clutch papers for use in automotive automatic transmissions. The ratio of cellulose and aramid is important for thermal and oxidation stability performance of wet clutches. High aramid wet clutch paper provides excellent durability performance. However, the cost of aramid fiber is high.

[0006] Further, regulatory changes require modern vehicles to have improved fuel economy and reduced emissions. In addition to improvements in the design of the engine and transmission systems, lubricant performance has also been required to address this issue. In the case of certain automotive transmissions, power loss caused by the torque converter in a starting time needs to be minimized and lock up clutch systems have been introduced to improve fuel efficiency. Lock-up torque converters are installed in lock-up wet paper clutches in the torque converter systems. These can reduce power loss and provide excellent fuel economy because they can engage the wet clutches after fluid coupling at low speeds and at a shorter time.

[0007] On the lubricant side, having the right lubricating oil composition for the automatic transmission with a lock-up paper wet clutch in the transmission is also very important. If the lubricating oil composition gives poor torque capacities and anti-shudder friction performance, power loss or uncomfortable vibration with high noise from lock-up of the wet clutch in the transmission would occur. Thus, lubricating oil compositions for an automatic transmission with lock-up paper wet clutch systems should provide both good fuel economy and smooth driving and operating conditions.

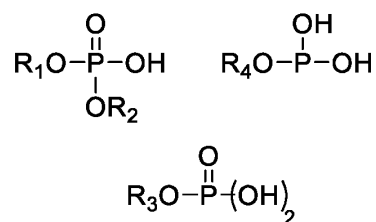
SUMMARY

[0008] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0009] The inventors have discovered a lubricating oil composition which has excellent wet paper clutch friction characteristics, such as anti-shudder performance, and which can also maintain excellent wet clutch torque capacity and durability of wet clutch friction characteristics.

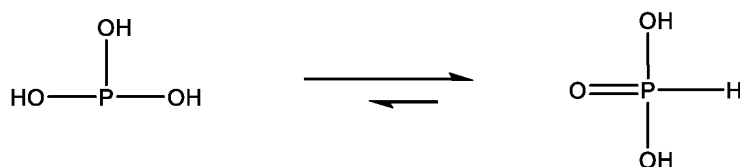
[0010] In one aspect, the disclosure relates to a lubricating oil composition comprising: a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of 2 to 12 mm²/s. The lubricating oil composition includes (a) one or more ashless dispersants; and (b) at least one acidic phosphorus compound (B1) selected from the group

consisting of: phosphoric acid, a phosphorus compound of the following structures, and a combination thereof:



wherein R₁-R₃ are independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety. R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety.

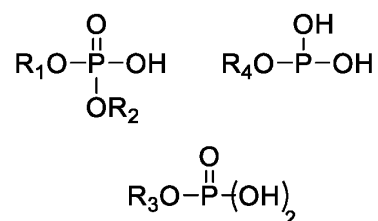
[0011] When R₄ is a hydrogen atom, the resulting phosphorous compound (B1) is phosphorous acid which can exist in tautomeric forms:



[0012] When the at least one acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compound (B2) selected from the group consisting of: phosphate tri-esters, phosphite esters, hydrogen phosphite ester, thiophosphate esters, amine salts of acidic phosphate esters, and amine salts of acidic phosphonic acid esters. The neutralization ratio of the (a) one or more ashless dispersants per the (b) at least one acidic phosphorus compound (B1) is 60 to 100%. The lubricating oil composition further includes (c) at least one friction modifier (C1) which is a reaction product of hydrocarbyl-substituted succinic anhydride with a polyamine, and (d) at least one friction modifier (C2) selected from the oiliness agent group consisting of diols, ethoxylated amines, fatty acid esters, sulfurized fatty acid esters, amides, and alcohols.

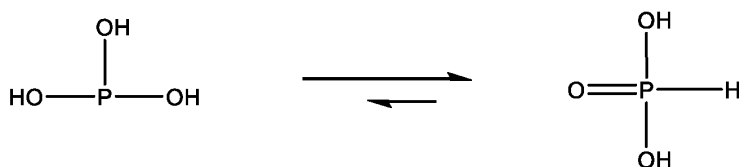
[0013] In another aspect, the disclosure relates to a method of improving anti-shudder performance in an automatic transmission. The method includes lubricating a transmission with a lubricating oil composition. The lubricating oil composition includes: a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of 2 to 12 mm²/s. The lubricating oil composition includes (a) one or more ashless dispersants; and (b) at least

one acidic phosphorus compound (B1) selected from the group consisting of: phosphoric acid, a phosphorus compound of the following structures, and a combination thereof:



wherein R₁-R₃ are independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety. R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety.

[0014] When R₄ is a hydrogen atom, the resulting phosphorous compound (B1) is phosphorous acid which can exist in tautomeric forms:



[0015] When the at least one acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compound (B2) selected from the group consisting of: phosphate tri-esters, phosphite esters, hydrogen phosphite esters, thiophosphate esters, amine salts of acidic phosphate esters, and amine salts of acidic phosphonic acid esters. The neutralization ratio of the (a) one or more ashless dispersants / the (b) at least one acidic phosphorus compound (B1) is 60 to 100%. The lubricating oil composition further includes (c) at least one friction modifier (C1) which is a reaction product of alkenyl-substituted succinic anhydride with a polyamine, and (d) at least one friction modifier (C2) selected from the oiliness agent group consisting of diols, ethoxylated amines, fatty acid esters, sulfurized fatty acid esters, amides, and alcohols.

DETAILED DESCRIPTION

Definitions

[0016] The following terms will be used throughout the specification and will have the following meanings unless otherwise indicated.

[0017] The term “a major amount” of a base oil refers to where the amount of the base oil is at least 40 wt. % of the lubricating oil composition. In some embodiments, “a major amount” of a base oil refers to an amount of the base oil more than 50 wt. %, more than 60 wt. %, more than 70 wt. %, more than 80 wt. %, or more than 90 wt. % of the lubricating oil composition.

[0018] The term “ashless” with regard to a dispersant of the lubricating oil composition means that the dispersant is substantially free of metals.

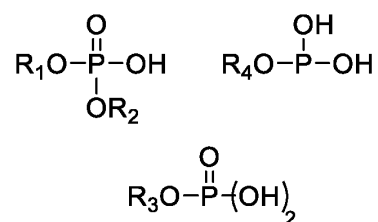
[0019] The term “Total Base Number” or “TBN” refers to the level of alkalinity expressed as mg KOH/g (the equivalent number of milligrams of KOH needed to neutralize 1 gram of a product) of a component or composition, which indicates the ability of the component or composition to continue to neutralize corrosive acids, in accordance with ASTM Standard No. D2896 or equivalent procedure. Therefore, a high TBN reflects strongly overbased products and, as a result, a higher base reserve for neutralizing acids.

[0020] The term “Total Acid Number” or “TAN” refers to the level of acidity of a component or composition, in accordance with ASTM Standard No. D664 or equivalent procedure.

Lubricating Oil Composition

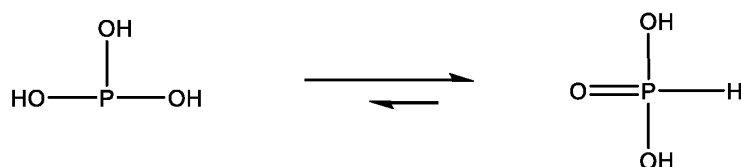
[0021] The disclosure generally relates to a lubricating oil composition which provides excellent wet paper clutch friction characteristics, such as anti-shudder performance, and which can also maintain excellent wet clutch torque capacity and durability of wet clutch friction characteristics.

[0022] The lubricating oil composition generally includes an oil of lubricating viscosity having a kinematic viscosity at 100 °C of 2 to 12 mm²/s. The lubricating oil composition also includes (a) one or more ashless dispersants; and (b) at least one acidic phosphorus compound (B1) selected from the group consisting of: phosphoric acid, a phosphorus compound of the following structures, and a combination thereof:



wherein R₁-R₃ are independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety. R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety.

[0023] When R₄ is a hydrogen atom, the resulting phosphorous compound (B1) is phosphorous acid which can exist in tautomeric forms:



[0024] When the at least one acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compound (B2) selected from the group consisting of: phosphate tri-esters, phosphite esters, hydrogen phosphite esters, thiophosphate esters, and amine salts thereof.

[0025] The neutralization ratio of the (a) one or more ashless dispersants per the (b) at least one acidic phosphorus compound (B1) present in the lubricating oil composition is 60 to 100 %.

[0026] The lubricating oil composition further includes (c) at least one friction modifier (C1) which is a reaction product of hydrocarbyl-substituted succinic anhydride with a polyamine, and (d) at least one friction modifier (C2) selected from the oiliness agent group consisting of diols, ethoxylated amines, fatty acid esters, sulfurized fatty acid esters, amides, and alcohols.

[0027] The following sections discuss the components of various embodiments of the lubricating oil composition in detail, provide example lubricating oil compositions, and disclose test results demonstrating excellent anti-shudder performance achieved by the lubricating oil composition.

The Oil of Lubricating Viscosity

[0028] The lubricating oil compositions disclosed herein generally include at least one oil of lubricating viscosity. Any base oil known to a skilled artisan can be used as the oil of lubricating viscosity disclosed herein. Some base oils suitable for preparing the lubricating oil compositions have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapters 1 and 2 (1996); and A. Sequeria, Jr., "Lubricant Base Oil and Wax Processing," New York, Marcel Decker, Chapter 6, (1994); and D. V. Brock, Lubrication Engineering, Vol. 43, pages 184-5, (1987), all of which are incorporated herein by reference. Generally, the amount of the base oil in the lubricating oil composition may be from 70 wt. % to 99.5 wt. %, based on the total weight of the lubricating oil composition. In some embodiments, the amount of the base oil in the lubricating oil composition is at least 75 wt. %, or at least 80 wt. %, and not greater than 99 wt. %, or not greater than 98.5 wt. %, or not greater than 98 wt. %, based on the total weight of the lubricating oil composition.

[0029] In certain embodiments, the base oil is or includes any natural or synthetic lubricating base oil fraction. Some non-limiting examples of synthetic oils include oils, such as polyalphaolefins or PAOs, prepared from the polymerization of at least one alpha-olefin, such as ethylene, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases, such as the Fisher-Tropsch process. In certain embodiments, the base oil includes less than 10 wt. % of one or more heavy fractions, based on the total weight of the base oil. A heavy fraction refers to a lube oil fraction having a viscosity of at least 20 cSt at 100 °C. In certain embodiments, the heavy fraction has a viscosity of at least 25 cSt or at least 30 cSt at 100 °C. As an example, the heavy fraction may have a viscosity ranging from 20 cSt, 25 cSt, or 30 cSt up to 25 cSt, 30 cSt, or 35 cSt at 100 °C. In further embodiments, the amount of the one or more heavy fractions in the base oil is less than 10 wt. %, less than 5 wt. %, less than 2.5 wt. %, less than 1 wt. %, or less than 0.1 wt. %, based on the total weight of the base oil. In still further embodiments, the base oil includes no heavy fraction.

[0030] In certain embodiments, the lubricating oil compositions include a major amount of a base oil of lubricating viscosity. In some embodiments, the base oil has a kinematic viscosity at 100 °C. of at least 1.5 centistokes (cSt), or at least 2 centistokes (cSt), and not greater than 20 cSt, or not greater than 16 cSt. The kinematic viscosity of the base oils or the lubricating oil compositions disclosed herein can be measured according to ASTM D 445, which is incorporated herein by reference.

[0031] In other embodiments, the base oil is or includes a base stock or blend of base stocks. In further embodiments, the base stocks are manufactured using a variety of different processes including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. In some embodiments, the base stocks include a rerefined stock. In further embodiments, the rerefined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use.

[0032] In some embodiments, the base oil includes one or more of the base stocks in one or more of Groups I-V as specified in the American Petroleum Institute (API) Publication 1509, Fourteen Edition, December 1996 (i.e., API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils), which is incorporated herein by reference. The API guideline defines a base stock as a lubricant component that may be manufactured using a variety of different processes. Groups I, II and III base stocks are mineral oils, each with specific ranges of the amount of saturates, sulfur content and viscosity index. Group IV base stocks are polyalphaolefins (PAO). Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

[0033] In some embodiments, the base oil includes one or more of the base stocks in Group I, II, III, IV, V or a combination thereof. In other embodiments, the base oil includes one or more of the base stocks in Group II, III, IV or a combination thereof. In further embodiments, the base oil includes one or more of the base stocks in Group II, III, IV or a combination thereof wherein the base oil has a kinematic viscosity of at least 1.5 centistokes (cSt), or at least 2 cSt, and not greater than 20 cSt, or not greater than 16 cSt at 100 °C. In some embodiments, the base oil is a mixture of a Group II base oil and a Group III base oil.

[0034] The base oil may be selected from the group consisting of natural oils of lubricating viscosity, synthetic oils of lubricating viscosity and mixtures thereof. In some embodiments, the base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocracked base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. In other embodiments, the base oil of lubricating viscosity includes natural oils, such as animal oils, vegetable oils, mineral oils (e.g., liquid petroleum oils and solvent treated or acid-treated mineral oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types), oils derived from coal or shale, and combinations thereof. Some non-limiting examples of animal oils include bone oil, lanolin, fish oil, lard oil, dolphin oil, seal oil, shark oil, tallow oil, and whale oil. Some non-limiting examples of vegetable oils include castor oil, olive oil, peanut oil, rapeseed oil, corn

oil, sesame oil, cottonseed oil, soybean oil, sunflower oil, safflower oil, hemp oil, linseed oil, tung oil, oiticica oil, jojoba oil, and meadow foam oil. Such oils may be partially or fully hydrogenated.

[0035] In some embodiments, the synthetic oils of lubricating viscosity include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and inter-polymerized olefins, alkylbenzenes, polyphenyls, alkylated diphenyl ethers, alkylated diphenyl sulfides, as well as their derivatives, analogues and homologues thereof, and the like. In other embodiments, the synthetic oils include alkylene oxide polymers, interpolymers, copolymers and derivatives thereof wherein the terminal hydroxyl groups can be modified by esterification, etherification, and the like. In further embodiments, the synthetic oils include the esters of dicarboxylic acids with a variety of alcohols. In certain embodiments, the synthetic oils include esters made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers. In further embodiments, the synthetic oils include tri-alkyl phosphate ester oils, such as tri-n-butyl phosphate and tri-iso-butyl phosphate.

[0036] In some embodiments, the synthetic oils of lubricating viscosity include silicon-based oils (such as the polyalkyl-, polyaryl-, polyalkoxy-, polyaryloxy-siloxane oils and silicate oils). In other embodiments, the synthetic oils include liquid esters of phosphorus-containing acids, polymeric tetrahydrofurans, polyalphaolefins, and the like.

[0037] Base oil derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base oil. Such wax isomerate oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

[0038] In further embodiments, the base oil includes a poly-alpha-olefin (PAO). In general, the poly-alpha-olefins may be derived from an alpha-olefin having from 2 to 30, from 2 to 20, or from 2 to 16 carbon atoms. Non-limiting examples of suitable poly-alpha-olefins include those derived from octene, decene, mixtures thereof, and the like. These poly-alpha-olefins may have a viscosity of at least 1.5 centistokes and not greater than 15 centistokes, or not greater than 12 centistokes, or not greater than 8 centistokes at 100 °C. In some instances, the poly-alpha-olefins may be used together with other base oils such as mineral oils, synthetic esters or alkylated naphthalene base oils.

[0039] In further embodiments, the base oil includes a polyalkylene glycol or a polyalkylene glycol derivative, where the terminal hydroxyl groups of the polyalkylene

glycol may be modified by esterification, etherification, acetylation and the like. Non-limiting examples of suitable polyalkylene glycols include polyethylene glycol, polypropylene glycol, polyisopropylene glycol, and combinations thereof. Non-limiting examples of suitable polyalkylene glycol derivatives include ethers of polyalkylene glycols (e.g., methyl ether of polyisopropylene glycol, diphenyl ether of polyethylene glycol, diethyl ether of polypropylene glycol, etc.), mono- and polycarboxylic esters of polyalkylene glycols, and combinations thereof. In some instances, the polyalkylene glycol or polyalkylene glycol derivative may be used together with other base oils such as poly- α -olefins and mineral oils.

[0040] In further embodiments, the base oil includes any of the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, and the like) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, and the like). Non-limiting 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 like.

[0041] In further embodiments, the base oil includes a hydrocarbon prepared by the Fischer-Tropsch process. The Fischer-Tropsch process prepares hydrocarbons from gases containing hydrogen and carbon monoxide using a Fischer-Tropsch catalyst. These hydrocarbons may require further processing in order to be useful as base oils. For example, the hydrocarbons may be dewaxed, hydroisomerized, and/or hydrocracked using processes known to a person of ordinary skill in the art.

[0042] In further embodiments, the base oil includes an unrefined oil, a refined oil, a rerefined oil, or a mixture thereof. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. Non-limiting examples of unrefined oils include shale oils obtained directly from retorting operations, petroleum oils obtained directly from primary distillation, and ester oils obtained directly from an esterification process and used without further treatment. Refined oils are similar to the unrefined oils except the former have been further treated by one or more purification processes to improve one or more properties. Many such purification processes are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base

extraction, filtration, percolation, and the like. Rerefined oils are obtained by applying to refined oils processes similar to those used to obtain refined oils. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally treated by processes directed to removal of spent additives and oil breakdown products.

Ashless Dispersant

[0043] The lubricating oil composition includes at least one ashless dispersant (A). According to example embodiments, the lubricating oil compositions includes one or more nitrogen-containing ashless succinimide dispersant(s). According to certain embodiments, the one or more nitrogen-containing ashless succinimide dispersant is a non-post treated dispersant.

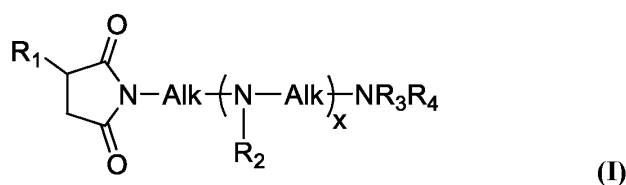
[0044] Typical examples of the nitrogen-containing ashless dispersant include hydrocarbyl succinimides such as alkenyl or alkyl succinimides derived from polyolefins, and derivatives thereof. A succinimide can be obtained by a reaction between a succinic anhydride substituted with a high molecular weight alkenyl or alkyl group, and a polyalkylenepolyamine containing an average of at least 3 or 4 nitrogen atoms per molecule and not greater than 7 or not greater than 10 nitrogen atoms per molecule. In one aspect, the high molecular weight alkenyl or alkyl group is typically a polyolefin with a number average molecular weight of approximately 500 to 5000, with polyisobutene being particularly favorable. In one aspect, the high molecular weight alkenyl or alkyl group is typically a polyolefin with a number average molecular weight of at least 500, or at least 700, or at least 800, or at least 900, or at least 950, and not greater than 4000, or not greater than 3000, or not greater than 2000, or not greater than 1050. For example, the polyolefin could have a number average molecular weight of 1000.

[0045] In some aspects, a chlorination method in which chlorine is utilized in the step of obtaining a polybutenyl succinic anhydride by a reaction between polybutene and maleic anhydride. With this method, however, although reactivity is good, a large amount of chlorine (such as 2000 ppm) ends up remaining in the final succinimide product. On the other hand, if a thermal reaction is used in which no chlorine is involved, the amount of chlorine remaining in the final product can be kept to a very low level (such as 40 ppm or less). Also, compared to conventional polybutene (primarily one having a β -olefin structure), using highly reactive polybutene (one in which at least 50% has a methyl vinylidene structure) is advantageous in that reactivity is increased even with a thermal reaction method.

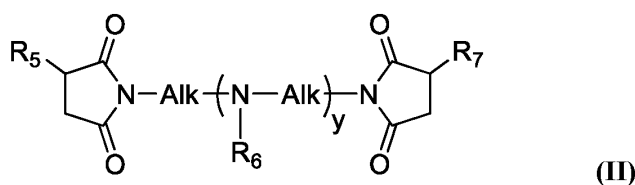
If reactivity is high, there will be less unreacted polybutene in the dispersant, so a dispersant with a high concentration of active component (succinimide) can be obtained. Therefore, it is possible to manufacture a succinimide by first obtaining a polybutenyl succinic anhydride by thermal reaction using highly reactive polybutene, and then reacting this polybutenyl succinic anhydride with a polyamine. The succinimide can be used in the form of what is called a modified succinimide, by further reacting with boric acid, an alcohol, an aldehyde, a ketone, an alkylphenol, a cyclic carbonate, an organic acid, or the like. A boron-containing alkenyl (or alkyl) succinimide obtained by a reaction with boric acid or a boron compound is particularly advantageous in terms of thermal and oxidation stability. Succinimides come in mono, bis, tris, and poly types, according to the number of imide structures per molecule, but bis types are typically used as the succinimide in the lubricating oil composition.

[0046] Other examples of nitrogen-containing ashless dispersants include polymeric succinimide dispersants derived from an ethylene- α -olefin copolymer (such as one with a molecular weight of 1000 to 15,000), and alkenylbenzylamine-based ashless dispersants.

[0047] Example nitrogen-containing ashless dispersants are mono and bis alkyl or alkenyl succinimides derived from the reaction of alkyl or alkenyl succinic acid or anhydride and alkylene polyamines. These compounds are generally considered to have the formula (I):



wherein R_1 is a substantially hydrocarbon chain having a molecular weight from 500 to 3000, that is, R_1 is a hydrocarbyl chain, such as an alkenyl radical, containing 40 to 200 carbon atoms; Alk is an alkylene chain of 2 to 10, or 2 to 6, carbon atoms, R_2 , R_3 , and R_4 are selected from a C_1 - C_4 alkyl or alkoxy or alkylamine or hydrogen, typically hydrogen, and x is an integer from 0 to 10, typically 0 to 3; or formula (II):



wherein R_5 and R_7 are both a substantially hydrocarbon chain having a molecular weight from 500 to 3000, that is, R_5 and R_7 are each a hydrocarbyl chain, such as an alkenyl chain,

containing 30 to 220 carbon atoms; Alk is an alkylene chain of 2 to 10, typically 2 to 6, carbon atoms, R₆ is selected from a C₁- C₄ alkyl or alkoxy or alkylamine or hydrogen, typically hydrogen, and y is an integer from 0 to 10, typically 0 to 3. In one embodiment, R₁, R₅ and R₇ are polyisobutyl groups.

[0048] In some embodiments, R₂ or R₆ is part of a cyclic ring, wherein the cyclic ring includes 2 or more nitrogen atoms.

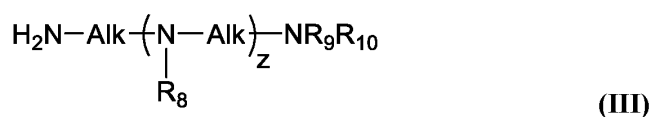
[0049] In one embodiment, the actual reaction product of alkylene or alkenylene succinic acid or anhydride and alkylene polyamine will include the mixture of compounds including monosuccinimides and bissuccinimides. The mono alkenyl succinimide and bis alkenyl succinimide produced may depend on the charge mole ratio of polyamine to succinic groups and the particular polyamine used. Charge mole ratios of polyamine to succinic groups of 1:1 may produce predominantly mono alkenyl succinimide. Charge mole ratios of polyamine to succinic group of 1:2 may produce predominantly bis alkenyl succinimide. Examples of succinimide dispersants include those described in, for example, U.S. Pat. Nos. 3,172,892, 4,234,435 and 6,165,235, which are herein incorporated by reference in their entirety.

[0050] In one embodiment, the polyalkenes from which the substituent groups are derived are typically homopolymers and interpolymers of polymerizable olefin monomers of 2 to 16 carbon atoms, and usually 2 to 6 carbon atoms. The amines which are reacted with the succinic acylating agents to form the carboxylic dispersant composition can be monoamines or polyamines.

[0051] In one aspect of the disclosure, the alkenyl succinimide may be prepared by reacting a polyalkylene succinic anhydride with an alkylene polyamine. The polyalkylene succinic anhydride is the reaction product of a polyalkylene (typically polyisobutene) with maleic anhydride. One can use conventional polyisobutene, or high methylvinylidene polyisobutene in the preparation of such polyalkylene succinic anhydrides. One can use thermal, chlorination, free radical, acid catalyzed, or any other process in this preparation. Examples of suitable polyalkylene succinic anhydrides are thermal PIBSA (polyisobutenyl succinic anhydride) described in U.S. Pat. No. 3,361,673; chlorination PIBSA described in U.S. Pat. No. 3,172,892; a mixture of thermal and chlorination PIBSA described in U.S. Pat. No. 3,912,764; high succinic ratio PIBSA described in U.S. Pat. No. 4,234,435; PolyPIBSA described in U.S. Pat. Nos. 5,112,507 and 5,175,225; high succinic ratio PolyPIBSA

described in U.S. Pat. Nos. 5,565,528 and 5,616,668; free radical PIBSA described in U.S. Pat. Nos. 5,286,799, 5,319,030, and 5,625,004; PIBSA made from high methylvinylidene polybutene described in U.S. Pat. Nos. 4,152,499, 5,137,978, and 5,137,980; high succinic ratio PIBSA made from high methylvinylidene polybutene described in European Patent Application Publication No. EP 355 895; terpolymer PIBSA described in U.S. Pat. No. 5,792,729; sulfonic acid PIBSA described in U.S. Pat. No. 5,777,025 and European Patent Application Publication No. EP 542 380; and purified PIBSA described in U.S. Pat. No. 5,523,417 and European Patent Application Publication No. EP 602 863. The disclosures of each of these documents are incorporated herein by reference in their entirety. The polyalkylene succinic anhydride is typically a polyisobutenyl succinic anhydride. In one example embodiment, the polyalkylene succinic anhydride is a polyisobutenyl succinic anhydride that is derived from a polyisobutylene having a number average molecular weight of at least 500, or at least 600, or at least 700, or at least 800, or at least 900, and not greater than 1400, or not greater than 1300, or not greater than 1200, or not greater than 1100, or not greater than 1000.

[0052] The typical polyalkylene amines used to prepare the succinimides are of the formula (III):



wherein z is an integer of from 0 to 10 and Alk is an alkylene radical of 2 to 10, typically 2 to 6, carbon atoms, R₈, R₉, and R₁₀ are selected from a C₁-C₄ alkyl or alkoxy or alkylamine or hydrogen, typically hydrogen, and z is an integer from 0 to 10, typically 0 to 3.

[0053] The alkylene amines include principally methylene amines, ethylene amines, butylene amines, propylene amines, pentylene amines, hexylene amines, heptylene amines, octylene amines, other polymethylene amines and also the cyclic and the higher homologs of such amines as piperazine and amino alkyl-substituted piperazines. They are exemplified specifically by ethylene diamine, triethylene tetraamine, propylene diamine, decamethyl diamine, octamethylene diamine, diheptamethylene triamine, tripropylene tetraamine, tetraethylene pentamine, trimethylene diamine, pentaethylene hexamine, ditrimethylene triamine, 2-heptyl-3-(2-aminopropyl)-imidazoline, 4-methyl imidazoline, N,N-dimethyl-1,3-propane diamine, 1,3-bis(2-aminoethyl)imidazoline, 1-(2-aminopropyl)-piperazine, 1,4-bis(2-aminoethyl)piperazine and 2-methyl-1-(2-aminobutyl)piperazine. Higher homologs are

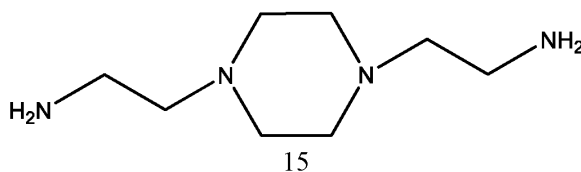
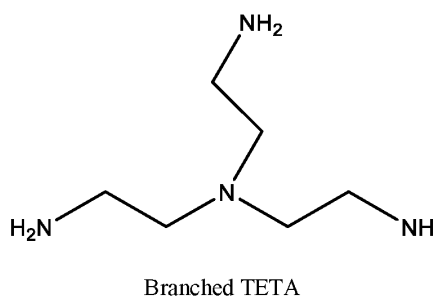
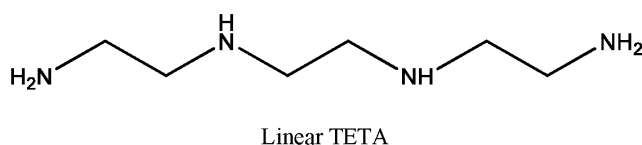
obtained by condensing two or more of the above-illustrated alkylene amines likewise are useful.

[0054] The ethylene amines are especially useful. They are described in some detail under the heading “Ethylene Amines” in the Encyclopedia of Chemical Technology, Kirk-Othmer, Vol. 5, pp. 898-905 (Interscience Publishers, New York, 1950). The term “ethylene amine” is used in a generic sense to denote a class of polyamines conforming for the most part to the formula (IV):

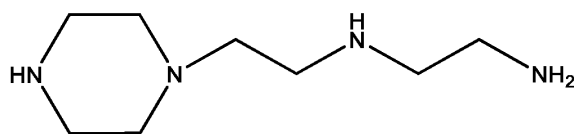


wherein α is an integer from 1 to 10. In one embodiment, α is an integer 3 to 5. Thus, it includes, for example, ethylene diamine, diethylene triamine (DETA), triethylene tetraamine (TETA), tetraethylene pentamine, pentaethylene hexamine, and the like.

[0055] It should be understood that the polyamines used herein often include a mixture of polyamine products. For example, triethylenetetramine (TETA) that is commercially available from Huntsman is described as a mixture of linear TETA, branched TETA, BIS aminoethylpiperazine (BIS AEP), and N-[(2-aminoethyl) 2-aminoethyl]piperazine) or PEEDA.



Bis AEP



PEEDA

[0056] The individual alkenyl succinimides used in the alkenyl succinimide composition can be prepared by conventional processes, such as disclosed in U.S. Pat. Nos. 2,992,708; 3,018,250; 3,018,291; 3,024,237; 3,100,673; 3,172,892; 3,202,678; 3,219,666; 3,272,746; 3,361,673; 3,381,022; 3,912,764; 4,234,435; 4,612,132; 4,747,965; 5,112,507; 5,241,003; 5,266,186; 5,286,799; 5,319,030; 5,334,321; 5,356,552; 5,716,912, the disclosures of which are all hereby incorporated by reference in their entirety for all purposes.

[0057] Also included within the term “alkenyl succinimides” are post-treated succinimides such as post-treatment processes involving borate or ethylene carbonate disclosed by Wollenberg, et al., U.S. Pat. No. 4,612,132; Wollenberg, et al., U.S. Pat. No. 4,746,446; and the like as well as other post-treatment processes each of which are incorporated herein by reference in its entirety. The carbonate-treated alkenyl succinimide is typically a polyisobutene succinimide derived from polyisobutenes having a molecular weight of at least 500, or at least 900, or at least 1,300, or at least 2,000, and not greater than 3,000, or not greater than 2,500, or not greater than 2,400, or not greater than 2,300.

[0058] In one embodiment, the dispersant system is present in an amount of at least 1 wt. %, or at least 1.5 wt. %, or at least 2.0 wt. % and not greater than 20 wt. %, or not greater than 15 wt. %, or not greater than 10 wt. %, or not greater than 5.0 wt. %, or not greater than 4.0 wt. %, or not greater than 3.0 wt. %, for example 1.0 - 3.0 wt. %, based on the total weight of the lubricating oil composition.

[0059] In another embodiment, the non-post treated dispersant is a non-post treated succinimide dispersant. In other embodiments, the non-post treated succinimide dispersant is present in an amount of at least 0.3 wt. %, or at least 0.5 wt. %, or at least 0.6 wt. %, and not greater than 8 wt. %, or not greater than 5 wt. %, or not greater than 4 wt. %, or not greater than 3.0 wt. %, or not greater than 2.0 wt. %, based on the total weight of the lubricating oil composition.

[0060] The individual alkenyl succinimides used in the alkenyl succinimide composition can be prepared by conventional processes, such as disclosed in U.S. Pat. Nos. 2,992,708; 3,018,250; 3,018,291; 3,024,237; 3,100,673; 3,172,892; 3,202,678; 3,219,666; 3,272,746; 3,361,673; 3,381,022; 3,912,764; 4,234,435; 4,612,132; 4,747,965; 5,112,507; 5,241,003; 5,266,186; 5,286,799; 5,319,030; 5,334,321; 5,356,552; 5,716,912, the disclosures of which are all incorporated by reference herein in their entirety for all purposes.

[0061] Also included within the term “alkenyl succinimides” are post-treated succinimides such as post-treatment processes involving borate or ethylene carbonate disclosed for example in U.S. Pat. No. 4,612,132, U.S. Pat. No. 4,746,446, and the like as well as other post-treatment processes each of which are incorporated herein by reference in its entirety. Typically, the carbonate-treated alkenyl succinimide is a polybutene succinimide derived from polybutenes having a molecular weight of at least 500, or at least 600, or at least 800, or at least 900, and not greater than 3000, or not greater than 2500, or not greater than 2300.

[0062] According to example embodiments, the nitrogen-containing ashless succinimide dispersants each have a number average molecular weight of at least 500, at least 750, or at least 850, or at least 1000, and not greater than 1800, or not greater than 1700, or not greater than 1600, or not greater than 1500, or not greater than 1400, or not greater than 1350.

[0063] Each nitrogen-containing ashless succinimide dispersant typically has a TBN of at least 25 mg KOH/g or at least 30 mg KOH/g, and not greater than 55 mg KOH/g or not greater than 50 mg KOH/g.

[0064] The nitrogen content of each nitrogen-containing ashless succinimide dispersant according to the example embodiments ranges from 1.0 wt. % to 3.0 wt. %, based on the total weight of the nitrogen-containing ashless succinimide dispersant.

[0065] In one embodiment, the dispersant is not post treated. In another embodiment, the dispersant is post treated with a boron compound.

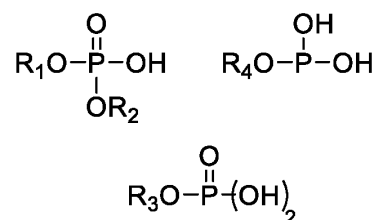
[0066] According to the example embodiment, the one or more nitrogen-containing ashless succinimide dispersant(s) includes a boron-containing dispersant. The boron content of this nitrogen-containing ashless succinimide dispersant ranges from 0.1 wt. % to 2.0 wt. %, based on the total weight of the nitrogen-containing ashless succinimide dispersant.

[0067] According to an example embodiment, the one or more nitrogen-containing ashless succinimide dispersants includes two dispersants. The first dispersant is a boron-modified polyisobutenyl succinimide with a polyisobutene number average molecular weight of 1300, a nitrogen content of 1.95 wt. %, a boron content of 0.63 wt. %, and a TBN of 46 mg KOH/g. The second dispersant is a polyisobutenyl succinimide with a polyisobutene number average molecular weight of 1000, a nitrogen content of 1.93 wt. %, and a TBN of 35 mg KOH/g.

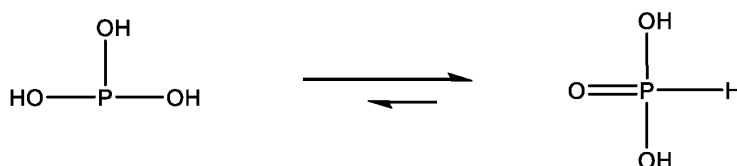
[0068] The lubricating oil composition typically includes less than 0.3 wt. % of sulfated ash, or not greater than 0.1 wt. % sulfated ash, based in the total weight of the lubricating oil composition.

Phosphorous Compound

[0069] The lubricating oil composition further includes at least one phosphorous compound. A variety of different phosphorous compounds can be used in the lubricating oil composition. However, according to example embodiments, the lubricating oil composition includes at least one acidic phosphorus compound (B1) selected from phosphoric acid or a phosphorus compound of the following structures, or a combination thereof:



where R₁-R₃ is independently a C₁-C₂₀ hydrocarbyl group that may optionally contain an ether or thioether moiety. R₄ is a hydrogen atom or a C₁-C₂₀ hydrocarbyl group that may optionally contain an ether or thioether moiety. When R₄ is a hydrogen atom, the resulting phosphorous compound (B1) is phosphorous acid which can exist in tautomeric forms:



[0070] According to example embodiments, when the acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compounds (B2) selected from phosphate tri-esters,

phosphite esters, hydrogen phosphite esters, thiophosphate esters, amine salts of acidic phosphate esters, and amine salts of acidic phosphonic acid esters.

Phosphoric Acid

[0071] The phosphoric acid of the lubricating oil composition is typically an 85 wt. % solution of inorganic phosphoric acid H_3PO_4 . According to example embodiments, the phosphoric acid (85 wt. % solution) includes phosphorus in an amount of at least 20.0 wt. %, or at least 25.0 wt. %, and not greater than 32.0 wt. %, or not greater than 30.0 wt. %, based on the total weight of the phosphoric acid.

[0072] According to example embodiments, the phosphoric acid (85 wt. % solution) has a total acid number (TAN) of at least 850 mg KOH/g or at least 950 mg KOH/g, and not greater than 1050 mg KOH/g or not greater than 1000 mg KOH/g.

[0073] In one embodiment, the phosphoric acid (85 wt. % solution) is present in an amount of 0.01 wt. % to 1.0 wt. %, based on the total weight of the lubricating oil composition. In other embodiments, the phosphoric acid is present in an amount of at least 0.01 wt. %, or at least 0.02 wt. %, or at least 0.03 wt. %, and not greater than 0.5 wt. %, or not greater than 0.6 wt. %, or not greater than 0.7 wt. %, or not greater than 1.0 wt. %, based on the total weight of the lubricating oil composition.

Acid mono or di Phosphate Esters

[0074] In certain embodiments the phosphorus compound may include an acid mono or di-phosphate ester. Examples of the phosphate esters include mono- and/or di-aryl phosphates, mono- and/or di alkyl phosphates, mono- and/or alkyl-aryl phosphates, mono- and/or aryl-alkyl phosphates, and mono- and/or di-alkenyl phosphates. Specific examples include mono- and/or di-phenyl phosphate, mono- and/or di-cresyl phosphate, benzyl phenyl phosphate, ethyl phenyl phosphate, mono- and/or di-butyl phosphate, ethyl butyl phosphate, cresyl phenyl phosphate, ethyl-phenyl phenyl phosphate, propyl-phenyl phenyl phosphate, phosphate, di-ethylphenyl phosphate, di-propyl-phenyl phosphate, butylphenyl phenyl phosphate, di-butylphenyl phosphate, di-hexyl phosphate, di-(2-ethylhexyl)phosphate, di-octyl phosphate, di-decyl phosphate, di-lauryl phosphate, di-myristyl phosphate, di-palmityl phosphate, di-stearyl phosphate, and di-oleyl phosphate.

[0075] A thioether bond may be contained in the alkyl group. Examples of the phosphate esters containing a thioether include mono- and/or di alkyl thiophosphates, mono- and/or di-butyl thioethyl phosphate, mono- and/or di-hexyl thioethyl phosphate, mono- and/or di-octyl thioethyl phosphate, mono- and/or di-decyl thioethyl phosphate, mono- and/or di-dodecyl thioethyl phosphate, mono- and/or di-hexadecyl thioethyl phosphate.

[0076] According to example embodiments, each acid mono- and/or di-phosphate ester has a phosphorous content of 3.0 wt. % to 20.0 wt. % and a sulfur content of 5.0 wt. % to 15.0 wt. %, based on the total weight of the phosphate ester.

[0077] The lubricating oil composition may include phosphorus in an amount of at least 0.01 wt. %, or at least 0.02 wt. %, or at least 0.03 wt. %, and not greater than 0.20 wt. %, or not greater than 0.1 wt. %, or not greater than 0.08 wt. %, based on the total weight of the lubricating oil composition.

Neutral Phosphate Esters

[0078] Examples of the phosphate esters include triaryl phosphates, trialkyl phosphates, trialkylaryl phosphates, triarylalkyl phosphates, and trialkenyl phosphates. Specific examples include triphenyl phosphate, tricresyl phosphate, benzyl diphenyl phosphate, ethyl diphenyl phosphate, tributyl phosphate, ethyl dibutyl phosphate, cresyl diphenyl phosphate, dicresyl phenyl phosphate, ethylphenyl diphenyl phosphate, di(ethylphenyl)phenyl phosphate, propylphenyl diphenyl phosphate, di(propylphenyl)phenyl phosphate, triethylphenyl phosphate, tripropylphenyl phosphate, butylphenyl diphenyl phosphate, di(butylphenyl)phenyl phosphate, tributylphenyl phosphate, trihexyl phosphate, tri(2-ethylhexyl)phosphate, tri-octyl phosphate, tridecyl phosphate, trilauryl phosphate, trimyristyl phosphate, tripalmityl phosphate, tristearyl phosphate, and trioleyl phosphate.

Phosphite esters

[0079] Examples of the phosphite esters include triethyl phosphite, tributyl phosphite, triphenyl phosphite, tricresyl phosphite, tri(nonylphenyl)phosphite, tri(2-ethylhexyl)phosphite, tridecyl phosphite, trilauryl phosphite, triisooctyl phosphite, diphenyl isodecyl phosphite, tristearyl phosphite, and trioleyl phosphite.

[0080] A thioether bond may be contained in the alkyl group. Examples of the phosphite esters containing a thioether include tri-alkyl thiophosphites, tri-butyl thioethyl

phosphite, tri-hexyl thioethyl phosphite, tri-octyl thioethyl phosphite, tri-decyl thioethyl phosphite, tri-dodecyl thioethyl phosphite, and tri-hexadecyl thioethyl phosphite.

[0081] According to example embodiments, each phosphite ester has a phosphorous content of 3.0 wt. % to 15.0 wt. %. When the phosphite ester includes a thioether bond, the phosphite ester has a sulfur content of 5.0 wt. % to 25.0 wt. %, based on the total weight of the phosphite ester.

Hydrogen phosphite esters

[0082] The hydrogen phosphite is in certain embodiments a hydrogen phosphite di-alkyl ester, a hydrogen di-phenyl ester, a hydrogen di-alkyl-phenyl ester is preferable, but the present invention is not limited thereto. Example of the hydrogen phosphite di-esters include di-butyl hydrogen phosphite, di-pentyl hydrogen phosphite, di-hexyl hydrogen phosphite, di-octyl hydrogen phosphite, di-2 ethyl hexyl hydrogen phosphite, di-decyl hydrogen phosphite, di-lauryl hydrogen phosphite, di-octadecyl hydrogen phosphite, di-phenyl hydrogen phosphite etc.

[0083] A thioether bond may be contained in the alkyl group. Examples of the hydrogen phosphite esters containing a thioether include di-alkyl hydrogen thiophosphites, di-butyl thioethyl hydrogen phosphite, di-hexyl thioethyl hydrogen phosphite, di-octyl thioethyl hydrogen phosphite, di-decyl thioethyl hydrogen phosphite, di-dodecyl thioethyl hydrogen phosphite, and di-hexadecyl thioethyl hydrogen phosphite.

[0084] According to example embodiments, each hydrogen phosphite ester has a phosphorous content of 3.0 wt. % to 15.0 wt. %. In embodiments where the hydrogen phosphite ester includes a thioether bond, the hydrogen phosphite ester has a sulfur content of 5.0 wt. % to 25.0 wt. %, based on the total weight of the phosphite ester.

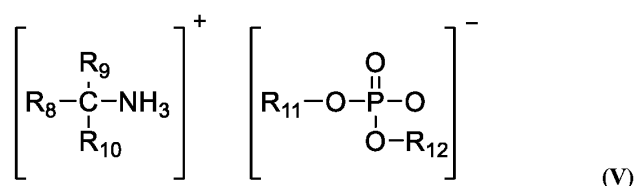
Amine Salts

[0085] As noted above, according to example embodiments, when the acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compounds (B2) which may include amine salts of acidic phosphate esters or amine salts of acidic phosphorous acid esters. Examples of such amine salts include an amine salt of mono-hexyl phosphate, an amine salt of di-hexyl phosphate, an amine salt of mono-2 ethyl-hexyl phosphate, an amine salt of di-2 ethyl hexyl phosphate, an amine salt of mono-octyl phosphate, an amine salt of di-

octyl phosphate, an amine salt of mono-octyl thiophosphate, an amine salt of di-octyl thiophosphate, amine salt of mono-decyl phosphate, an amine salt of mono dodecyl phosphate, an amine salt of di-dodecyl phosphate, an amine salt of mono-octadecyl phosphate, and an amine salt of di-octadecyl phosphate.

[0086] The amine used to produce the amine salt may be represented by $R_5R_6R_7N$. R_5 , R_6 and R_7 are, independently, saturated or unsaturated aliphatic, aromatic, or aromatic aliphatic hydrocarbons having 1 to 20 carbon atoms, or hydrogen. When the group is a hydrocarbon, it may be a linear structure or a branched chain.

[0087] In certain embodiments, the amine salt may be represented by the formula (V):



where R_8 is C_9 to C_{22} hydrocarbyl, R_9 and R_{10} are each independently C_1 to C_4 hydrocarbyl, R_{11} is C_{10} to C_{20} hydrocarbyl, and R_{12} is hydrogen or C_{10} to C_{20} hydrocarbyl. Examples of such amine salts are described in U.S. Patent No. 5,552,068, which is incorporated by reference herein in its entirety.

[0088] According to example embodiments, each amine salt has a phosphorous content of 3.0 wt. % to 15.0 wt. % and a nitrogen content of 0.5 wt. % to 5.0 wt. %, based on the total weight of the amine salt.

Example Phosphorus Compounds

[0089] According to example embodiments, the one or more neutral phosphorus compound(s) (B2) are present in an amount of 0.01 wt. % to 3.0 wt. %, based on the total weight of the lubricating oil composition. In other embodiments, the one or more neutral phosphorus compound(s) (B2) are present in an amount of at least 0.01 wt. %, or at least 0.02 wt. %, or at least 0.03 wt. %, and not greater than 1.0 wt. %, or not greater than 0.5 wt. %, or not greater than 0.3 wt. %, or not greater than 0.2 wt. %, based on the total weight of the lubricating oil composition.

[0090] According to an example embodiment, the lubricating oil composition includes inorganic phosphoric acid H_3PO_4 as the only acidic phosphorus compound (B1). The inorganic phosphoric acid H_3PO_4 (85 wt. % solution) has a phosphorous content of 27.0

wt. %, based on the total weight of the inorganic phosphoric acid and has a total acid number (TAN) of 973 mg KOH/g. In this embodiment, the lubricating oil composition further includes the one or more neutral phosphorus compound (B2) selected from phosphate esters, phosphite esters, hydrogen phosphite esters, thiophosphate esters, amine salts of acidic phosphate esters, and amine salts of acidic phosphorous acid esters.

[0091] According to one embodiment, the lubricating oil composition includes a phosphite ester, particularly a mixture of monoalkyl phosphite ester (an acidic phosphorous compound) containing thioether alkyl groups and dialkyl phosphite ester containing thioether alkyl groups. The mixture of mono/dialkyl phosphite ester containing thioether alkyl groups has a phosphorus content of 8.0 wt. % and a sulfur content of 8.4 wt. %, based on the total weight of the mixture, and a TAN of 111 mg KOH/g.

[0092] According to another example embodiment, the lubricating oil composition includes diphenyl hydrogen phosphite having a phosphorus content of 13.3 wt. %, based on the total weight of the diphenyl hydrogen phosphite.

[0093] In another example embodiment, the lubricating oil composition includes a phosphate amine, such as an amine salt of an alkyl phosphate ester. In one embodiment the phosphate amine salt has a phosphorus content of 8.2 wt. % and a nitrogen content of 1.8 wt. %, based on the total weight of the alkyl amine salt.

[0094] According to example embodiments, the at least one phosphorous compound of the lubricating oil composition includes the inorganic phosphoric acid H_3PO_4 in combination with the mixture of mono/dialkyl phosphite ester containing thioether alkyl groups. According to another example embodiment, the lubricating oil composition includes the inorganic phosphoric acid H_3PO_4 , the mixture of mono/dialkyl phosphite ester containing thioether alkyl groups, the diphenyl hydrogen phosphite, and the alkyl amine salt of an alkyl phosphate ester. According to another example embodiment, the at least one phosphorous compound of the lubricating oil composition includes only the mixture of mono/dialkyl phosphite ester containing thioether alkyl groups. According to yet another example embodiment, the lubricating oil composition includes the mixture of mono/dialkyl phosphite ester containing thioether alkyl groups, the diphenyl hydrogen phosphite, and the alkyl amine salt of an alkyl phosphate ester. According to another example embodiment, the lubricating oil composition includes the inorganic phosphoric acid H_3PO_4 , the diphenyl hydrogen phosphite, and the alkyl amine salt of an alkyl phosphate ester.

Neutralization Ratio

[0095] A significant feature of the lubricating oil composition of the present disclosure is the neutralization of the at least one ashless dispersant (A) by the at least one acidic phosphorous compound (B1) – expressed herein by a neutralization ratio and/or an initial pH of the composition. It has been found, for instance, that in some embodiments, polyamine is bound to the dispersant, and the basic nitrogen of this polyamine is adsorbed on the oxide film on the metal surface, which reduces the effect of the anti-wear agent, or is adsorbed on the paper material of the wet clutch, which reduces the effect of the FM. The effect of the oiliness agent is also negatively affected. By appropriately controlling the amount of basic amine, the effectiveness of additives such as anti-wear agents, oiliness agents and FM will change significantly. On the other hand, if the oil is excessively neutralized with acid and the oil becomes strongly acidic, rust and corrosion can occur. Therefore, it is desirable that the oil is in an appropriate range (pH = 6 to 9). The neutralization ratio is the percentage of the at least one ashless dispersant (A) that is neutralized by the at least one acidic phosphorous compound (B1).

[0096] The neutralization ratio of the lubricating oil composition is calculated by dividing the Total Acid Number (TAN) of the acidic phosphorus compound(s) by the Total Base Number of the ashless dispersant(s). The TAN is the total TAN provided by the one or more acidic phosphorus compound(s) together; and the TBN is the TBN of the one or more ashless dispersant(s) together. The TAN is measured by the ASTM D664 method; and the TBN is measured by the ASTM D4739 method. By way of non-limiting example, the neutralization ratio may be determined according to the following steps: (a) measure the base value of each dispersant (A) in accordance with ASTM D4739; (b) measure the acid value of each acidic phosphorus compound (B1) in accordance with ASTM D664; and (c) multiply the values determined for (a) and (b) by the amount of weight percent added for their respective components to the formulation to calculate the total base value from the dispersant (A) and the total acid value from the acidic phosphorous compound (B1). The percentage of the total base value of the dispersant that can be neutralized by the total acid value of the acidic phosphorus compounds is calculated by dividing the total base value by the total acid value and multiplying by 100.

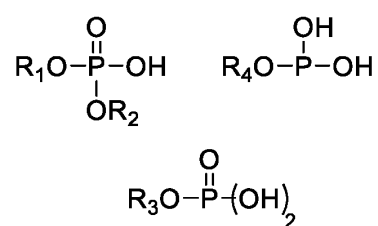
[0097] According to example embodiments, the neutralization ratio of the lubricating oil composition is at least 60 % or at least 75 % and not greater than 120 % or not greater

than 100 %. A neutralization ratio of 60 to 100 % means that 60 percent to 100 percent of the ashless dispersant(s) is/are neutralized by the acidic phosphorous compound(s).

Initial pH (i-pH) by ASTM D664

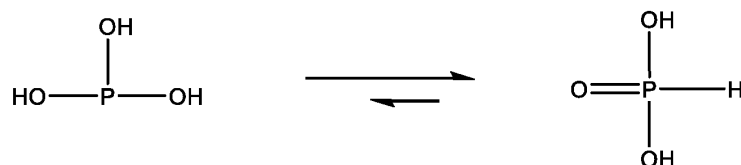
[0098] As noted above, the initial pH (i-pH) of the present compositions can be used to express the neutralization of the at least one ashless dispersant (A) by the at least one acidic phosphorous compound (B1). The i-pH may be determined by, for example, mixing the dispersant (A in Table 1) and the acidic phosphorus (B1 in Table 1) at a temperature of 50 to 80 °C for 30 minutes, and returning the resulting mixture to room temperature in the same manner as in a normal blend. The extent to which this mixture is neutralized can be understood by looking at the i-pH measured by the potentiometric titration method of ASTM D664. The mixture of dispersant (A in Table 1) and acidic phosphorus compound(s) (B1 in Table 1) is dissolved in a mixed solvent of toluene, 2-propanol and water, and the acidity (or basicity) was measured by a pH meter before titration. The first pH value indicated by the pH meter before titration is the i-pH. This value indicates the acidity (or basicity) of the mixture. This i-pH measurement is often used not only for confirming the acidity (or basicity) of such a mixture, but also for the maintenance of lubricating oil in the general market. It is often used as a method to judge the degree of deterioration (oxidation) of used oil. According to example embodiments, the pH is at least 4 and less than 10, between 4 and 9.5, or between 4.5 and 9.5.

[0099] As discussed above, the at least one acidic phosphorous compound (B1) is selected from phosphoric acid or a phosphorus compound of the following structures, or a combination thereof:



where R₁-R₃ is independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety. R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety.

[0100] When R₄ is a hydrogen atom, the resulting phosphorous compound (B1) is phosphorous acid which can exist in tautomeric forms:



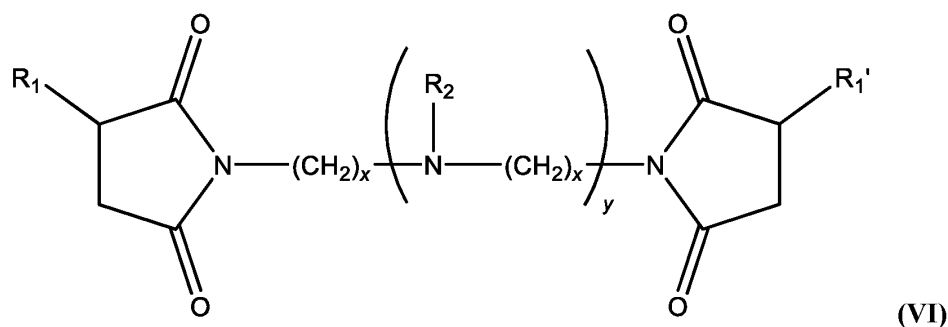
[0101] The at least one ashless dispersant (A) includes one or more nitrogen-containing ashless succinimide dispersant(s).

Friction Modifier

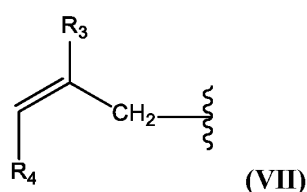
[0102] A variety of known friction modifiers can be used as friction modifiers in the lubricating oil composition of the present disclosure.

[0103] The friction modifiers can include a reaction product of hydrocarbyl succinic acid or anhydride and polyamine. According to certain embodiments, the actual reaction product of the hydrocarbyl succinic acid or anhydride and polyamine can include a mixture of compounds including monosuccinimides and bissuccinimides. The mono succinimide and bis succinimide produced may depend on the charge mole ratio of polyamine to succinic groups and the particular polyamine used. Charge mole ratios of polyamine to succinic groups of about 1:1 may produce predominantly mono succinimide. Charge mole ratios of polyamine to succinic groups of about 1:2 may produce predominantly bis succinimide. According to certain embodiments, the friction modifiers include a low molecular weight C6 to C30 hydrocarbyl-substituted succinimide.

[0104] According to other example embodiments, the friction modifier of the lubricating oil composition is a bissuccinimide. The bissuccinimide friction modifier could be an hydrocarbyl-substituted succinimide represented by the following formula (VI) or a post-treated derivative thereof:



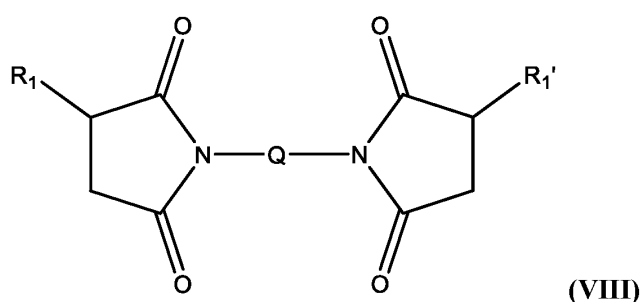
[0105] wherein each of R_1 and R_1' independently is a hydrocarbyl group having a branch structure in the β -position which is represented by the following formula (VII); R_2 is a hydrogen atom, an alkyl group having 1 to 12 carbon atoms, an aryl group having 6 to 12 carbon atoms, an aralkyl group having 7 to 13 carbon atoms, an alkylamine, or a 5-8 membered heterocyclic group; x is an integer of 1 to 6; and y is an integer of 0 to 20:



in which each of R_3 and R_4 is an aliphatic hydrocarbyl group, and the total number of carbon atoms in R_3 and R_4 is in the range of 3 to 30, under the condition that the number of carbon atoms in R_3 is larger than the number of carbon atoms in R_4 by 3, or the number of carbon atoms in R_3 is smaller than the number of carbon atoms in R_4 by 1.

[0106] In some embodiments, R_2 is part of a cyclic ring, wherein the cyclic ring includes 2 or more nitrogen atoms.

[0107] According to another embodiment, the friction modifier includes an alkenyl-substituted succinimide of the following formula (VIII) or a post-treated derivative thereof:



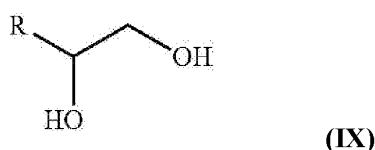
[0108] in which each of R_1 and R_1' independently is a hydrocarbyl group having a branch structure in the β -position which is derived from a dimer of a single linear β -olefin having 3 to 24 carbon atoms, and Q is a residue of a polyamine having 1 to 20 carbon atoms.

[0109] The friction modifier can provide improved friction performance as evidenced by an increased friction coefficient and a prolonged friction coefficient stability to the lubricating oil composition. Therefore, the lubricating oil composition containing the friction

modifier can keep an automatic transmission from shuddering for a relatively long period of time.

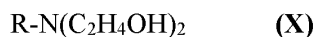
[0110] According to another embodiment, the friction modifiers include a post-treated alkenyl-substituted succinimide which is obtained by post-treatment of the alkenyl-substituted succinimide with a known post-treating agent such as boric acid, phosphoric acid, a carboxylic acid, or ethylene carbonate.

[0111] According to certain embodiments, the friction modifiers of the lubricating oil composition include a diol. For example, the lubricating oil composition can include a diol compound having the following formula (IX):



wherein R represents hydrogen, an alkyl group or an alkenyl group. It is also possible to use a mixture of a compound having different alkyl or alkenyl groups. The alkyl or alkenyl groups can either be straight or branched and typically include 10-30 carbon atoms.

[0112] According to other embodiments, the friction modifiers of the lubricating oil composition include an ethoxylated amine. The ethoxylated amine can have the following formula (X):



wherein R represents hydrogen, an alkyl group or an alkenyl group. It is also possible to use a mixture of a compound having different alkyl or alkenyl groups. The alkyl or alkenyl groups can either be straight or branched and typically include 8-22 carbon atoms.

[0113] According to certain embodiments, the friction modifiers of the lubricating oil composition include a fatty acid ester, fatty acid amide, fatty acid amides of low molecular weight amino acid, and/or alcohol. Examples of the fatty acid ester include those disclosed in U.S. Patent No. 3,933,659, which is incorporated by reference herein in its entirety.

[0114] According to example embodiments, the lubricating oil composition includes a combination of at least one friction modifier (C1) that is a reaction product of hydrocarbyl-substituted succinic anhydride with a polyamine, and at least one friction modifier (C2) selected from diols, ethoxylated amines, fatty acid esters, and alcohols.

[0115] Each friction modifier is typically present in an amount of 0.01 wt. % to 3 wt. %, based on the total weight of the lubricating oil composition. The total amount of friction modifiers present in the lubricating oil composition is typically 0.01 wt. % to 5 wt. %, based on the total weight of the lubricating oil composition. In example embodiments, the friction modifier is present in an amount of at least 0.01 wt. %, or at least 0.05 wt. %, or at least 0.1 wt. %, and not greater than 4.0 wt. %, or not greater than 3.0 wt. %, or not greater than 2.0 wt. %, based on the total weight of the lubricating oil composition.

Other Additives

[0116] Optionally, the lubricating oil composition may further include at least one additive or a modifier (hereinafter designated as “additive”) that can impart or improve any desirable property of the lubricating oil composition. Any additive known to a person of ordinary skill in the art may be used in the lubricating oil composition disclosed herein. Some suitable additives are 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. In some embodiments, the at least one additive can be selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides, and combinations thereof. The additives can also include friction modifiers and dispersants in addition to the friction modifiers and dispersants described above.

[0117] The concentration of each of the additives in the lubricating oil composition, when used, individually is typically at least 0.001 wt. %, or at least 0.01 wt. %, or at least 0.1 wt. %, and not greater than 15 wt. %, or not greater than 10 wt. %, or not greater than 8 wt. %, based on the total weight of the lubricating oil composition. Further, the total amount of the additives in the lubricating oil composition together is typically at least 0.001 wt. %, or at least 0.1 wt. %, or at least 1 wt. %, and not greater than 20 wt. %, or not greater than 15 wt. %, or not greater than 10 wt. %, for example 9 wt. % to 10 wt. %, based on the total weight of the lubricating oil composition.

[0118] In one embodiment, the lubricating oil composition contains a metal detergent compound. Some non-limiting examples of suitable metal detergent include sulfurized or unsulfurized alkyl or alkenyl phenates, alkyl or alkenyl aromatic sulfonates, borated sulfonates, sulfurized or unsulfurized metal salts of multi-hydroxy alkyl or alkenyl aromatic compounds, alkyl or alkenyl hydroxy aromatic sulfonates, sulfurized or unsulfurized alkyl or alkenyl naphthenates, metal salts of alkanolic acids, metal salts of an alkyl or alkenyl multiacid, and chemical and physical mixtures thereof. Other non-limiting examples of suitable metal detergents include metal sulfonates, phenates, salicylates, phosphonates, thiophosphonates and combinations thereof. The metal can be any metal suitable for making sulfonate, phenate, salicylate or phosphonate detergents. Non-limiting examples of suitable metals include alkali earth metals, alkaline metals and transition metals. In some embodiments, the metal is Ca, Mg, Ba, K, Na, Li or the like.

[0119] Some suitable detergents have been described in Mortier et al., “*Chemistry and Technology of Lubricants*,” 2nd Edition, London, Springer, Chapter 3, pages 75-85 (1996); and Leslie R. Rudnick, “*Lubricant Additives: Chemistry and Applications*,” New York, Marcel Dekker, Chapter 4, pages 113-136 (2003), both of which are incorporated herein by reference.

[0120] Generally, the amount of the metal detergent is from about 0.001 wt. % to about 0.5 wt. %, from about 0.01 wt. % to about 0.3 wt. %, from about 0.01 wt. % to about 0.2 wt. %, from about 0.01 wt. % to about 0.1 wt. %, about 0.02 wt. % to about 0.5 wt. %, about 0.02 wt. % to about 0.4 wt. %, or from about 0.03 wt. % to about 0.3 wt. %, based on the total weight of the lubricating oil composition.

[0121] In one embodiment, the metal detergent is a calcium sulfonate or salicylate detergent with a TBN of 50 to 450 mg KOH/gm and a calcium content of 1.0 to 20 wt.%.

[0122] In another embodiment, calcium is present at no more than 300 wt. ppm in the lubricating oil composition. In other embodiments, calcium is present at 25 to 300, 30 to 250, 34 to 250 wt. ppm in the lubricating oil composition.

[0123] According to some embodiments, the lubricating oil composition includes at least one antioxidant that can reduce or prevent the oxidation of the oil of lubricating viscosity or base oil. Any antioxidant known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable antioxidants include amine-based antioxidants (e.g., alkyl diphenylamines, phenyl-.alpha.-naphthylamine,

alkyl or aralkyl substituted phenyl-.alpha.-naphthylamine, alkylated p-phenylene diamines, tetramethyl-diaminodiphenylamine and the like), phenolic antioxidants (e.g., 2-tert-butylphenol, 4-methyl-2,6-di-tert-butylphenol, 2,4,6-tri-tert-butylphenol, 2,6-di-tert-butyl-p-cresol, 2,6-di-tert-butylphenol, 4,4'-methylenebis-(2,6-di-tert-butylphenol), 4,4'-thiobis(6-di-tert-butyl-o-cresol) and the like), sulfur-based antioxidants (e.g., dilauryl-3,3'-thiodipropionate, sulfurized phenolic antioxidants and the like), phosphorous-based antioxidants (e.g., phosphites and the like), zinc dithiophosphate, oil-soluble copper compounds and combinations thereof. The amount of the antioxidant may vary from at least 0.01 wt. %, or at least 0.05 wt. %, or at least 0.1 wt. %, and not greater than 10 wt. %, or not greater than 5 wt. %, or not greater than 3 wt. %, based on the total weight of the lubricating oil composition. Some suitable antioxidants have been described in Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker, Chapter 1, pages 1-28 (2003), which is incorporated herein by reference.

[0124] The lubricating oil composition can optionally include at least one pour point depressant that can lower the pour point of the lubricating oil composition. Any pour point depressant known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable pour point depressants include polymethacrylates, alkyl acrylate polymers, alkyl methacrylate polymers, di(tetra-paraffin phenol)phthalate, condensates of tetra-paraffin phenol, condensates of a chlorinated paraffin with naphthalene and combinations thereof. In some embodiments, the pour point depressant includes an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and phenol, polyalkyl styrene or the like. The amount of the pour point depressant may vary from at least 0.01 wt. %, or at least 0.05 wt. %, or at least 0.1 wt. %, and not greater than 10 wt. %, or not greater than 5 wt. %, or not greater than 3 wt. %, based on the total weight of the lubricating oil composition. Some suitable pour point depressants have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 6, pages 187-189 (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker, Chapter 11, pages 329-354 (2003), both of which are incorporated herein by reference.

[0125] The lubricating oil composition can further include at least one foam inhibitor or an anti-foam additive. Any foam inhibitor or anti-foam additive known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable anti-foam additives include silicone oils or polydimethylsiloxanes,

fluorosilicones, alkoxyated aliphatic acids, polyethers (e.g., polyethylene glycols), branched polyvinyl ethers, alkyl acrylate polymers, alkyl methacrylate polymers, polyalkoxyamines and combinations thereof. In some embodiments, the anti-foam additive includes glycerol monostearate, polyglycol palmitate, a trialkyl monothiophosphate, an ester of sulfonated ricinoleic acid, benzoylacetone, methyl salicylate, glycerol monooleate, or glycerol dioleate. The amount of the anti-foam additive may vary from at least 0.0001 wt. %, or at least 0.0005 wt. %, or at least 0.001 wt. %, and not greater than 1 wt. %, or not greater than 0.5 wt. %, or not greater than 0.1 wt. %, based on the total weight of the lubricating oil composition. Some suitable anti-foam additives have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 6, pages 190-193 (1996), which is incorporated herein by reference.

[0126] The lubricating oil composition can optionally include at least one corrosion inhibitor that can reduce corrosion. Any corrosion inhibitor known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable corrosion inhibitors include half esters or amides of dodecylsuccinic acid, phosphate esters, thiophosphates, alkyl imidazolines, sarcosines, benzotriazoles, thiadiazoles and combinations thereof. The amount of the corrosion inhibitor may vary from at least 0.001 wt. %, or at least 0.005 wt. %, and not greater than 5 wt. %, or not greater than 1 wt. %, or not greater than 0.5 wt. %, based on the total weight of the lubricating oil composition. Some suitable corrosion inhibitors have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 6, pages 193-196 (1996), which is incorporated herein by reference.

[0127] The lubricating oil composition disclosed herein can optionally include at least one extreme pressure (EP) agent that can prevent sliding metal surfaces from seizing under conditions of extreme pressure. Any extreme pressure agent known by a person of ordinary skill in the art may be used in the lubricating oil composition. Generally, the extreme pressure agent is a compound that can combine chemically with a metal to form a surface film that prevents the welding of asperities in opposing metal surfaces under high loads. Non-limiting examples of suitable extreme pressure agents include sulfurized animal or vegetable fats or oils, sulfurized animal or vegetable fatty acid esters, fully or partially esterified esters of trivalent or pentavalent acids of phosphorus, sulfurized olefins, dihydrocarbyl polysulfides, sulfurized Diels-Alder adducts, sulfurized dicyclopentadiene, sulfurized or co-sulfurized mixtures of fatty acid esters and monounsaturated olefins, co-

sulfurized blends of fatty acid, fatty acid ester and alpha-olefin, functionally-substituted dihydrocarbyl polysulfides, thia-aldehydes, thia-ketones, epithio compounds, sulfur-containing acetal derivatives, co-sulfurized blends of terpene and acyclic olefins, polysulfide olefin products, amine salts of phosphoric acid esters or thiophosphoric acid esters, and combinations thereof. The amount of the extreme pressure agent may vary from at least 0.01 wt. %, or at least 0.05 wt. %, or at least 0.1 wt. %, and not greater than 5 wt. %, or not greater than 3 wt. %, or not greater than 1 wt. %, based on the total weight of the lubricating oil composition. Some suitable extreme pressure agents have been described in Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker, Chapter 8, pages 223-258 (2003), which is incorporated herein by reference.

[0128] In one embodiment, the lubricating oil composition contains no sulfur based extreme pressure agent.

[0129] The lubricating oil composition disclosed herein can optionally include at least one rust inhibitor that can inhibit the corrosion of ferrous metal surfaces. Any rust inhibitor known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable rust inhibitors include oil-soluble monocarboxylic acids (e.g., 2-ethylhexanoic acid, lauric acid, myristic acid, palmitic acid, oleic acid, linoleic acid, linolenic acid, behenic acid, cerotic acid and the like), oil-soluble polycarboxylic acids (e.g., those produced from tall oil fatty acids, oleic acid, linoleic acid and the like), alkenylsuccinic acids in which the alkenyl group contains 10 or more carbon atoms (e.g., tetrapropenylsuccinic acid, tetradecenylsuccinic acid, hexadecenylsuccinic acid, and the like), long-chain alpha,omega-dicarboxylic acids having a molecular weight in the range of 600 to 3000 daltons, and combinations. The amount of the rust inhibitor may vary from at least 0.01 wt. %, or at least 0.05 wt. %, or at least 0.1 wt. %, and not greater than 10 wt. %, or not greater than 5 wt. %, or not greater than 3 wt. %, based on the total weight of the lubricating oil composition.

[0130] Other non-limiting examples of suitable rust inhibitors include nonionic polyoxyethylene surface active agents such as polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonyl phenyl ether, polyoxyethylene octyl phenyl ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monostearate, polyoxyethylene sorbitol mono-oleate, and polyethylene glycol mono-oleate. Further non-limiting examples of suitable rust inhibitors include stearic acid and other

fatty acids, dicarboxylic acids, metal soaps, fatty acid amine salts, metal salts of heavy sulfonic acid, partial carboxylic acid ester of polyhydric alcohol, and phosphoric ester.

[0131] In some embodiments, the lubricating oil composition includes at least one multifunctional additive. Some non-limiting examples of suitable multifunctional additives include sulfurized oxymolybdenum dithiocarbamate, sulfurized oxymolybdenum organophosphorodithioate, oxymolybdenum monoglyceride, oxymolybdenum diethylate amide, amine-molybdenum complex compound, and sulfur-containing molybdenum complex compound.

[0132] In certain embodiments, the lubricating oil composition includes at least one viscosity index improver. Some non-limiting examples of suitable viscosity index improvers include polymethacrylate type polymers, ethylene-propylene copolymers, styrene-isoprene copolymers, hydrated styrene-isoprene copolymers, polyisobutylene, and dispersant type viscosity index improvers.

[0133] In some embodiments, the lubricating oil composition includes at least one metal deactivator. Some non-limiting examples of suitable metal deactivators include disalicylidene propylenediamine, triazole derivatives, thiadiazole derivatives, and mercaptobenzimidazoles.

[0134] The additives disclosed herein may be in the form of an additive concentrate having more than one additive. The additive concentrate may include a suitable diluent, such as a hydrocarbon oil of suitable viscosity. Such diluent can be selected from the group consisting of natural oils (e.g., mineral oils), synthetic oils, and combinations thereof. Some non-limiting examples of the mineral oils include paraffin-based oils, naphthenic-based oils, asphaltic-based oils and combinations thereof. Some non-limiting examples of the synthetic base oils include polyolefin oils (especially hydrogenated alpha-olefin oligomers), alkylated aromatic, polyalkylene oxides, aromatic ethers, and carboxylate esters (especially diester oils) and combinations thereof. In some embodiments, the diluent is a light hydrocarbon oil, both natural or synthetic. Generally, the diluent oil can have a viscosity from 13 centistokes to 35 centistokes at 40°C.

[0135] Generally, it is desired that the diluent readily solubilizes the lubricating oil soluble additive and provides an oil additive concentrate that is readily soluble in the oil of lubricating viscosity, oil stock, or fuel. In addition, it is desired that the diluent not introduce any undesirable characteristics, including, for example, high volatility, high viscosity, and

impurities such as heteroatoms, to the oil of lubricating viscosity and thus, ultimately to the finished lubricant or fuel.

[0136] According to certain embodiments, the lubricating oil composition includes an oil soluble additive concentrate composition comprising an inert diluent, and the oil soluble additive concentrate composition is present in an amount of at least 2.0 wt. % or at least 10 wt. %, and not greater than 90 wt. % or not greater than 50 wt. %, based on the total weight of the lubricating oil composition.

Examples

[0137] The following examples are presented to demonstrate 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. 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.

[0138] Inventive lubricating oil compositions and comparative lubricating oil compositions were prepared from the following components and additives and evaluated for anti-wear performance. The example lubricating oil compositions include succinimide dispersant, acidic and neutral phosphorus additives (optional in some comparative examples), friction modifiers (optional in some comparative examples), other lubricating oil additives (detergents, antioxidants, metal deactivators, seal swell additives, foam inhibitors, and viscosity modifiers), and base oil.

[0139] Table 1 lists each lubricating oil composition, including the amount (wt. %) of each component. The inventive examples are non-limiting examples of the lubricating oil composition. The following specific components are present in the lubricating oil compositions of Table 1:

[0140] Dispersant A is a boron-modified polyisobutenyl succinimide with a polyisobutylene number average molecular weight of 1,300 (Nitrogen (N): 1.95 wt. %; Boron (B): 0.63 wt. %, TBN: 46 mg KOH/g).

[0141] Dispersant B is a polyisobutenyl succinimide with a polyisobutylene number average molecular weight of 1000 (Nitrogen (N): 1.93 wt. %, TBN: 35 mg KOH/g).

[0142] Dispersant C is a polyisobutenyl succinimide with a polyisobutene number average molecular weight of 550 (Nitrogen (N): 1.93 wt. %, TBN: 33 mg KOH/g).

[0143] Dispersant D is a polyisobutenyl succinimide with a polyisobutene number average molecular weight of 1000 (Nitrogen (N): 2.13 wt. %, TBN: 26 mg KOH/g).

[0144] Phosphorus compound 1 is inorganic phosphoric acid H_3PO_4 (85wt. % solution, Phosphorous (P): 27.0 wt. %, TAN: 973 mg KOH/g).

[0145] Phosphorus compound 2 is a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups (P: 8.0 wt. %, Sulfur (S): 8.4 wt. %, TAN: 111 mg KOH/g).

[0146] Phosphorus compound 3 is diphenyl hydrogen phosphite (P: 13.3 wt. %).

[0147] Phosphorus compound 4 is a monoalkyl amine salt of a dialkyl phosphate ester (P: 8.2 wt. %, N: 1.8 wt. %)

[0148] Phosphorus compound 5 is di-lauryl hydrogen phosphite (P: 7.24 wt%)

[0149] Friction Modifier 1 is a reaction product of C_{20} alkenyl-substituted succinic anhydride with diethylene triamine (N: 4.6 wt. %).

[0150] Friction Modifier 2 is an ethoxylated monoalkyl amine (N: 4.1 wt. %).

[0151] Friction Modifier 3 is a mixture of C_{16}/C_{18} diol.

[0152] The other additives present in the lubricating oil compositions include a mixture of detergents, antioxidants, metal deactivators, foam inhibitors, seal swell agents, and viscosity modifiers.

[0153] Table 1 also lists results of several tests conducted on the inventive and comparative lubricating oil compositions.

[0154] The above TBN measurements were obtained according to ASTM D4739 and the TAN measurements were obtained according to ASTM D664. The neutralization ratio of each example lubricating oil composition is listed in Table 1. The neutralization ratio was calculated as described above using the TBN and TAN values measured using ASTM D4739 and ASTM D664, respectively. The i-pH in the mixture of A (ashless dispersant(s)) and B1 (acidic phosphorus compound(s)) shown in Table 1 is measured according to ASTM D664 as described above. The other tests listed were performed as described herein.

Wet Clutch Anti-Shudder Performance Test

[0155] The Wet Clutch Anti-Shudder Performance Test was performed according to the JASO M349-2012 method. More specifically, the anti-shudder performance durability was determined by means of a low velocity friction apparatus according to “Road vehicles Test method for anti-shudder performance of automatic transmission fluids” as described in JASO M-349:2012.

[0156] The test was conducted using a friction plate containing cellulose and/or aramid fibers and a steel plate defined in JASO M349-2012 as the friction materials. Approximately 150 mL of lubricating oil was applied to the friction plate and steel plate. The break-in conditions included pressing the friction plate and steel plate together with a contact pressure of 1 MPa, and a lubricating oil temperature of 80° C. The sliding velocity of the friction plate along the steel plate was 0.6 m/s, and the sliding time was 30 minutes during break-in. The durability test conditions included pressing the friction plate and steel plate together with a contact pressure of 1 MPa, and a lubricating oil temperature of 120° C. The sliding velocity of the friction plate along the steel plate was 0.9 m/s, the slip time was 30 minutes, the rest time was 1 minute, and the performance measurement interval time was 6 hours during the durability test. A **positive value for the friction coefficient ($d\mu/dv$)** is indicative of anti-shudder performance. The anti-shudder duration was the same as the method described in JASO M349-12. The anti-shudder duration measures the duration required for the friction properties ($d\mu/dv$) to reach a negative value at a clutch slip speed of 0.3 m/s or 0.9 m/s at an oil temperature of 40 °C or 80 °C. A longer duration indicates better anti-shudder performance. As illustrated by the data of Table 1 below, the inventive example compositions 1-10 provide a significantly longer anti-shudder duration (198-612 hours) compared to the comparative example compositions (0-38 hours).

JASO SAE #2 Friction Test

[0157] The JASO SAE #2 Friction Test is a dynamic friction test and static friction test carried out by means of a SAE No.2 Tester according to “Friction Test Method for Automobiles and Automobile Automatic Transmission Fluid” as defined in JASO M348.2002 2012. The following parameters were used for this test:

[0158] Friction material plate: FZ127-24-Y12, Steel plate (FZ132-8Y2).

[0159] Dynamic Friction Measurement: inertial moment of inertia disc: 0.343 kgm. Oil temperature: 100° C. Rotation: 3,600 rpm, surface pressure of friction plate: 785 MPa. Test cycle: 30 sec./cycle, test number: 5,000 cycles.

[0160] Static Friction Measurement: rotation: 0.7 rpm. Oil temperature: 100° C. Surface pressure of friction plate: 785 MPa. Test period: 3 sec. after initiation of rotation. Test cycle: after 1, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 3000, 4000, and 5000 cycles.

[0161] Measurement: **Static friction coefficient (μ_s) at the maximum torque caused when the rotation at 0.7 rpm starts and static coefficient (μ_t) at the lapse of 2 seconds.**

[0162] Transmission torque capacity was evaluated by the value of μ_t @ 50, 500, and 5000 cycles.

Table 1

		Com p. 1	Com p. 2	Com p. 3	Com p. 4	Com p. 5	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6
A	Dispersant A	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
	Dispersant B	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Dispersant C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dispersant D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B1	P. compound 1	0.00	0.00	0.08	0.08	0.08	0.04	0.04	0.00	0.00	0.08	0.08
	P. compound 2	0.00	0.36	0.00	0.00	0.00	0.36	0.36	0.72	0.72	0.00	0.16
B2	P. compound 3	0.10	0.00	0.00	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.10
	P. compound 4	0.10	0.00	0.00	0.10	0.10	0.00	0.10	0.00	0.10	0.10	0.10
	P. compound 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Neutralization of dispersant: A with acidic phosphoric acid compound: B1	Neutralization Ratio	0	40	80	80	80	80	80	80	80	80	96
	i-pH (ASTM D664)	10.5	7.0	9.0	9.0	9.0	6.3	6.3	5.7	5.7	9.0	6.4
C1	FM 1	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C2	FM 2	0.03	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.03	0.03	0.03
	FM 3	0.10	0.10	0.10	0.10	0.00	0.10	0.10	0.10	0.10	0.10	0.10
	Other Additives	10.0	9.8	10.1	10.0	10.0	9.8	9.6	9.5	9.3	9.9	9.7
	Grp. II Base Oil	39.7	39.7	39.7	39.7	39.7	39.7	39.7	39.7	39.7	39.7	39.7
	Grp. III Base Oil	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5	46.5
	KV100 (cSt)	7.59	7.88	7.55	7.49	7.63	7.60	7.62	7.54	7.62	7.63	7.63
	Sulfated Ash (wt. %)	0.050	0.056	0.050	0.068	0.608	0.065	0.084	0.081	0.100	0.068	0.080
	P (ppm)	215	288	216	431	431	396	611	577	792	431	559
JASO SAE #2 friction test	μ t @ 50 cycles	0.133	0.134	0.140	0.122	0.150	0.131	0.124	0.131	0.125	0.125	0.121
	μ t @ 500 cycles	0.131	0.143	0.137	0.128	0.146	0.136	0.131	0.131	0.128	0.127	0.127
	μ t @ 5000 cycles	0.122	0.129	0.119	0.124	0.151	0.125	0.127	0.123	0.127	0.122	0.128
	μ 0/ μ d @50 cycles	0.961	1.01	1.04	1.03	1.03	1.04	1.00	1.03	0.99	0.95	0.97
	μ 0/ μ d @500 cycles	0.969	1.00	1.03	1.05	1.03	1.02	1.00	0.99	0.98	0.96	0.98
	μ 0/ μ d @5000 cycles	1.016	1.01	1.02	1.07	1.02	1.02	1.00	0.98	0.99	0.97	0.97
	μ d @50 cycles	0.128	0.130	0.138	0.130	0.133	0.128	0.126	0.129	0.125	0.132	0.132
	μ d @500 cycles	0.127	0.131	0.133	0.125	0.129	0.128	0.125	0.133	0.129	0.128	0.128

	μ d @5000 cycles	0.129	0.131	0.133	0.128	0.125	0.123	0.125	0.126	0.123	0.127	0.124
LVFA	Anti-shudder duration (hrs)	36	6	138	78	0	396	432	414	198	612	552

		Ex. 7	Ex. 8	Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14	Ex. 15	Ex. 16
A	Dispersant A	1.50	1.50	1.50	1.50	1.00	0.50	1.50	1.00	1.50	1.00
	Dispersant B	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Dispersant C	0.00	0.00	0.00	0.00	1.06	1.42	0.71	0.00	0.00	0.00
	Dispersant D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.92	1.37
B1	P. compound 1	0.08	0.08	0.00	0.06	0.06	0.05	0.07	0.06	0.07	0.06
	P. compound 2	0.00	0.00	0.86	0.36	0.00	0.00	0.00	0.00	0.00	0.18
B2	P. compound 3	0.10	0.12	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.00
	P. compound 4	0.10	0.12	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.00
	P. compound 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
Neutralization of dispersant: A with acidic phosphoric acid compound: B1	Neutralization Ratio	80	80	96	99	86	90	80	86	80	86
	i-pH (ASTM D664)	9.0	9.0	4.8	5.5	6.58	6.38	6.55	6.53	6.57	6.38
C1	FM 1	1.00	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
C2	FM 2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	FM 3	0.10	0.20	0.20	0.20	0.10	0.10	0.10	0.10	0.10	0.10
	Other Additives	9.9	9.9	9.9	9.9	4.9	4.9	5.0	4.9	4.9	4.9
	Grp. II Base Oil	86.2	85.9	85.3	85.8	61.4	61.6	61.2	61.1	61.0	61.0
	Grp. III Base Oil	0.0	0.0	0.0	0.0	30.0	30.0	30.0	30.0	30.0	30.0
	KV100 (cSt)	5.54	5.57	5.32	5.30	4.84	4.82	4.89	4.97	4.98	4.96
	Sulfated Ash (wt. %)	0.068	0.071	0.088	0.071	0.03	0.03	0.03	0.03	0.03	0.03
	P (ppm)	431	474	689	450	420	393	447	420	447	422
JASO SAE #2 friction test	μ t @ 50 cycles	0.122	0.125	0.132	0.132	0.117	0.110	0.115	0.114	0.113	0.112
	μ t @ 500 cycles	0.131	0.132	0.128	0.134	0.119	0.112	0.117	0.116	0.117	0.115
	μ t @ 5000 cycles	0.123	0.127	0.121	0.128	0.128	0.128	0.120	0.123	0.118	0.119
	μ 0/ μ d @50 cycles	0.98	0.96	1.03	1.00	0.961	0.961	0.954	0.946	0.923	0.962
	μ 0/ μ d @500 cycles	0.97	0.96	0.95	1.01	0.945	0.937	0.924	0.938	0.938	0.969
	μ 0/ μ d @5000 cycles	1.01	1.02	0.98	1.02	0.961	0.977	0.976	0.961	1.000	0.953

	μ d @50 cycles	0.133	0.136	0.131	0.130	0.127	0.127	0.130	0.129	0.130	0.133
	μ d @500 cycles	0.133	0.135	0.138	0.130	0.128	0.127	0.131	0.128	0.130	0.128
	μ d @5000 cycles	0.129	0.127	0.130	0.123	0.129	0.128	0.124	0.127	0.123	0.127
LVFA	Anti-shudder duration (hrs)	276	339	198	312	486	378	348	312	546	522

[0163] As shown in Table 1, Comparative examples 1 and 2 demonstrate poor friction characteristics and anti-shudder performance due to low neutralization of the basic dispersant. By contrast, inventive examples 1 and 2 containing sufficient acidic components (phosphorus compound 1 and 2) effectively neutralizes the basic dispersant to give excellent anti-shudder performance. Inventive example 6, which has nearly 100% neutralization rate, performs well in both the SAE #2 friction test and the LVFA anti-shudder test.

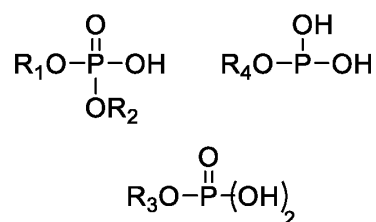
[0164] Inventive example 5 is illustrative of the need for additional neutral phosphorus compounds when only inorganic acid is used to neutralize the dispersant (see comparative example 3). When organic phosphorus acids are used, good friction characteristics and anti-shudder performance is observed without the need for additional phosphorus compounds as demonstrated in inventive examples 3 and 4. Friction modifiers are also a key component to providing adequate performance, as illustrated by the significant differences in friction and anti-shudder lifetime between inventive example 5 and those of comparative examples 4 and 5.

[0165] Inventive examples 7-10 also demonstrate that the additive combinations described herein are equally effective in low viscosity base oil formulations. Additional top treat of friction modifiers was shown to improve the anti-shudder performance further in a low viscosity baseline. Inventive examples 11-16 show that alternative dispersant types and combinations are also effective in the anti-shudder evaluation.

ADDITIONAL DESCRIPTION

[0166] The following non-limiting clauses are offered as additional description of various example embodiments of the present invention.

[0167] Embodiment 1. A lubricating oil composition comprising: a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of 2 to 12 mm²/s; (a) one or more ashless dispersants; (b) at least one acidic phosphorus compound (B1) selected from the group consisting of: phosphoric acid, a phosphorus compound of the following structures, and a combination thereof:



wherein R₁-R₃ are independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety; R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety; wherein when the at least one acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compound (B2) selected from the group consisting of: tri-phosphate esters, phosphite esters, hydrogen phosphite esters, thiosphosphate esters, and amine salts thereof; wherein the neutralization ratio of the (a) one or more ashless dispersants / the (b) at least one acidic phosphorus compound (B1) is 60 to 100; (c) at least one friction modifier (C1), wherein the friction modifier is a reaction product of alkenyl-substituted succinic anhydride with a polyamine; and (d) at least one friction modifier (C2) selected from the oiliness agent group consisting of diols, ethoxylated amines, fatty acid esters, sulfurized fatty acid esters, amides and alcohols.

[0168] Embodiment 2. The lubricating oil composition of embodiment 1 including phosphorus in an amount of 0.01 wt. % to 0.20 wt. %, based on the total weight of the lubricating oil composition.

[0169] Embodiment 3. The lubricating oil composition of any preceding embodiment including sulfated ash in an amount less than 0.3 wt. %, based on the total weight of the lubricating oil composition.

[0170] Embodiment 4. The lubricating oil composition of any preceding embodiment, wherein the neutralization ratio is 60 to 100 %.

[0171] Embodiment 5. The lubricating oil composition of any preceding embodiment, wherein the at least one acidic phosphorus compound (B1) includes a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups.

[0172] Embodiment 6. The lubricating oil composition of any preceding embodiment, wherein the at least one acidic phosphorus compound (B1) further includes phosphoric acid.

[0173] Embodiment 7. The lubricating oil composition of any preceding embodiment further including diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and an alkyl amine salt of an alkyl phosphate ester as the one or more neutral phosphorus compound (B2).

[0174] Embodiment 8. The lubricating oil composition of any preceding embodiment, wherein the at least one acidic phosphorus compound (B1) includes only phosphoric acid, and the one or more neutral phosphorus compound (B2) includes diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and an alkyl amine salt of an alkyl phosphate ester.

[0175] Embodiment 9. The lubricating oil composition of any preceding embodiment, wherein the one or more ashless dispersants includes polyisobutenyl succinimide; the at least one acidic phosphorus compound (B1) includes at least one of: phosphoric acid and a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups; the one or more neutral phosphorus compound (B2), if present, includes diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and/or an alkyl amine salt of an alkyl phosphate ester; the friction modifier (C1) includes a reaction product of C20 alkenyl-substituted succinic anhydride with diethylene triamine; and the at least one friction modifier (C2) includes an ethoxylated monoalkyl amine and/or a mixture of C16 and C18 diol.

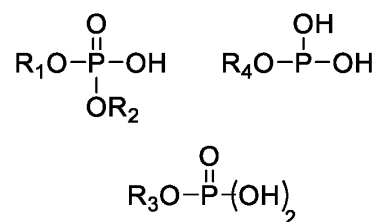
[0176] Embodiment 10. The lubricating oil composition of any preceding embodiment, wherein the base oil includes a mixture of a Group II base oil and a Group III base oil; and the lubricating oil composition further includes at least one of a detergent, antioxidant, metal deactivator, foam inhibitor, seal swell agent, and viscosity modifier.

[0177] Embodiment 11. The lubricating oil composition of any preceding embodiment, wherein the initial pH (i-pH) as determined by ASTM D664 of a mixture of A and B1 is 4 to 10.

[0178] Embodiment 12. The lubricating oil composition of any preceding embodiment, wherein the initial pH (i-pH) as determined by ASTM D664 of a mixture of A and B1 is 4.5 to 9.5.

[0179] Embodiment 13. A method of improving anti-shudder performance, comprising: lubricating a transmission with a lubricating oil composition, the lubricating oil composition including: a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of 2 to 12 mm²/s; (a) one or more ashless dispersants; (b) at least one

acidic phosphorus compound (B1) selected from the group consisting of: phosphoric acid, a phosphorus compound of the following structures, and a combination thereof:



wherein R₁-R₃ are independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety; R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety; wherein when the at least one acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compound (B2) selected from the group consisting of: phosphate esters, phosphite esters, hydrogen phosphite ester, thiosphosphate esters, and amine salts thereof; wherein the neutralization ratio of the (a) one or more ashless dispersants per the (b) at least one acidic phosphorus compound (B1) is 60 to 100 %; (c) at least one friction modifier (C1), wherein the friction modifier is a reaction product of alkenyl-substituted succinic anhydride with a polyamine; and (d) at least one friction modifier (C2) selected from the oiliness agent group consisting of diols, ethoxylated amines, fatty acid esters, sulfurized fatty acid esters, amides and alcohols.

[0180] Embodiment 14. The method of embodiment 13, wherein the lubricating oil composition includes phosphorus in an amount of 0.01 wt. % to 0.20 wt. %, based on the total weight of the lubricating oil composition.

[0181] Embodiment 15. The method of any preceding embodiment, wherein the lubricating oil composition includes sulfated ash in an amount of less than 0.3 wt. %, based on the total weight of the lubricating oil composition.

[0182] Embodiment 16. The method of any preceding embodiment, wherein the neutralization ratio of the lubricating oil composition is 60 to 100 %.

[0183] Embodiment 17. The method of any preceding embodiment, wherein the at least one acidic phosphorus compound (B1) includes at least one of phosphoric acid and a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups; and the one or more neutral phosphorus compound (B2) includes at least one of diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and an alkyl amine salt of an alkyl phosphate ester.

[0184] Embodiment 18. The method of any preceding embodiment, wherein the transmission is an automatic transmission or continuously variable transmission.

[0185] Embodiment 19. The method of any preceding embodiment, wherein the transmission includes a wet clutch system.

[0186] Embodiment 20. The method of any preceding embodiment, wherein the friction material used in the wet clutch system is a paper material that contains cellulose and/or aramid fibers.

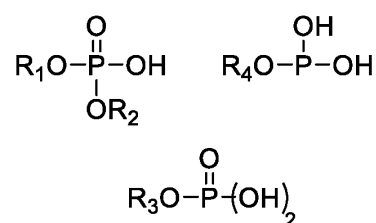
[0187] Embodiment 21. The method of any preceding embodiment, wherein the one or more ashless dispersants includes polyisobutenyl succinimide; the at least one acidic phosphorus compound (B1) includes at least one of: phosphoric acid and a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups; the one or more neutral phosphorus compound (B2), if present, includes diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and/or an alkyl amine salt of an alkyl phosphate ester; the friction modifier (C1) includes a reaction product of C20 alkenyl-substituted succinic anhydride with diethylene triamine; and the at least one friction modifier (C2) includes at least one of an ethoxylated monoalkyl amine and a mixture of C16 and C18 diol.

[0188] Embodiment 22. The method of any preceding embodiment, wherein the base oil of the lubricating oil composition includes a mixture of a Group II base oil and a Group III base oil; and the lubricating oil composition further includes at least one of a detergent, antioxidant, metal deactivator, foam inhibitor, seal swell agent, and viscosity modifier.

[0189] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms, and can also be used in any appropriate combination. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

CLAIMS

1. A lubricating oil composition comprising:
 a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of 2 to 12 mm²/s;
 (a) one or more ashless dispersants;
 (b) at least one acidic phosphorus compound (B1) selected from the group consisting of: phosphoric acid, a phosphorus compound of the following structures, and a combination thereof:

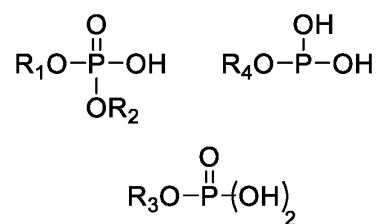


- wherein R₁-R₃ are independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety;
 wherein R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety
 wherein when the at least one acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compound (B2) selected from the group consisting of: phosphate esters, phosphite esters, hydrogen phosphite ester, thiosphosphate esters, and amine salts thereof;
 wherein the neutralization ratio of the (a) one or more ashless dispersants / the (b) at least one acidic phosphorus compound (B1) is 60 to 100 %;
 (c) at least one friction modifier (C1), wherein the friction modifier is a reaction product of alkenyl-substituted succinic anhydride with a polyamine; and
 (d) at least one friction modifier (C2) selected from the oiliness agent group consisting of diols, ethoxylated amines, fatty acid esters, sulfurized fatty acid esters, amides, and alcohols.

2. The lubricating oil composition of claim 1 including phosphorus in an amount of 0.01 wt. % to 0.20 wt. %, based on the total weight of the lubricating oil composition.
3. The lubricating oil composition of claim 1 including sulfated ash in an amount less than 0.3 wt. %, based on the total weight of the lubricating oil composition.

4. The lubricating oil composition of claim 1, wherein the neutralization ratio is 75 to 100 %.
5. The lubricating oil composition of claim 1, wherein the at least one acidic phosphorus compound (B1) includes a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups.
6. The lubricating oil composition of claim 5, wherein the at least one acidic phosphorus compound (B1) further includes phosphoric acid.
7. The lubricating oil composition of claim 1 including diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and an alkyl amine salt of an alkyl phosphate ester as the one or more neutral phosphorus compound (B2).
8. The lubricating oil composition of claim 1, wherein the at least one acidic phosphorus compound (B1) includes only phosphoric acid, and the one or more neutral phosphorus compound (B2) includes diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and an alkyl amine salt of an alkyl phosphate ester.
9. The lubricating oil composition of claim 1, wherein the one or more ashless dispersants includes polyisobutenyl succinimide; the at least one acidic phosphorus compound (B1) includes at least one of: phosphoric acid and a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups; the one or more neutral phosphorus compound (B2), if present, includes diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite and/or an alkyl amine salt of an alkyl phosphate ester; the friction modifier (C1) includes a reaction product of C20 alkenyl-substituted succinic anhydride with diethylene triamine; and the at least one friction modifier (C2) includes an ethoxylated monoalkyl amine and/or a mixture of C16 and C18 diol.
10. The lubricating oil composition of claim 9, wherein the oil of lubricating viscosity includes a mixture of a Group II base oil and a Group III base oil; and the lubricating oil composition further includes at least one of a detergent, antioxidant, metal deactivator, foam inhibitor, seal swell agent, and viscosity modifier.

11. The lubricating oil composition of claim 1, wherein the initial pH (i-pH) as determined by ASTM D664 of a mixture of A and B1 is 4 to 10.
12. The lubricating oil composition of claim 1, wherein the initial pH (i-pH) as determined by ASTM D664 of a mixture of A and B1 is 4.5 to 9.5.
13. A method of improving anti-shudder performance, comprising:
 lubricating a transmission with a lubricating oil composition, the lubricating oil composition including:
 a major amount of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of 2 to 12 mm²/s;
 (a) one or more ashless dispersants;
 (b) at least one acidic phosphorus compound (B1) selected from the group consisting of: phosphoric acid, a phosphorus compound of the following structures, and a combination thereof:



- wherein R₁-R₃ are independently a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety;
- wherein R₄ is a hydrogen atom or a C1-C20 hydrocarbyl group that may optionally contain an ether or thioether moiety
- wherein when the at least one acidic phosphorus compound (B1) is composed only of phosphoric acid, the lubricating oil composition additionally contains one or more neutral phosphorus compound (B2) selected from the group consisting of: phosphate esters, phosphite esters, hydrogen phosphite esters, thiosphosphate esters, and amine salts thereof;
- wherein the neutralization ratio of the (a) one or more ashless dispersants / the (b) at least one acidic phosphorus compound (B1) is 60 to 100 %;
- (c) at least one friction modifier (C1), wherein the friction modifier is a reaction product of alkenyl-substituted succinic anhydride with a polyamine; and

(d) at least one friction modifier (C2) selected from the oiliness agent group consisting of diols, ethoxylated amines, fatty acid esters, sulfurized fatty acid esters, amides and alcohols.

14. The method of claim 13, wherein the lubricating oil composition includes phosphorus in an amount of 0.01 wt. % to 0.20 wt. %, based on the total weight of the lubricating oil composition.

15. The method of claim 13, wherein the lubricating oil composition includes sulfated ash in an amount of less than 0.3 wt. %, based on the total weight of the lubricating oil composition.

16. The method of claim 13, wherein the neutralization ratio of the lubricating oil composition is 75 to 100 %.

17. The method of claim 13, wherein the at least one acidic phosphorus compound (B1) includes at least one of phosphoric acid and a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups; and the one or more neutral phosphorus compound (B2) includes at least one of diphenyl hydrogen phosphite, di-lauryl hydrogen phosphite, and an alkyl amine salt of an alkyl phosphate ester.

18. The method of claim 13, wherein the transmission is an automatic transmission or continuously variable transmission.

19. The method of claim 18, wherein the transmission includes a wet clutch system.

20. The method of claim 19, wherein the friction material used in the wet clutch system is a paper material that contains cellulose and/or aramid fibers.

21. The method of claim 13, wherein the one or more ashless dispersants includes polyisobutenyl succinimide; the at least one acidic phosphorus compound (B1) includes at least one of: phosphoric acid and a mixture of mono/dialkyl phosphite ester containing thioether alkyl groups; the one or more neutral phosphorus compound (B2), if present, includes diphenyl hydrogen phosphite and/or an alkyl amine salt of an alkyl phosphate ester;

the friction modifier (C1) includes a reaction product of C20 alkenyl-substituted succinic anhydride with diethylene triamine; and the at least one friction modifier (C2) includes at least one of an ethoxylated monoalkyl amine and a mixture of C16 and C18 diol.

22. The method of claim 13, wherein the base oil of the lubricating oil composition includes a mixture of a Group II base oil and a Group III base oil; and the lubricating oil composition further includes at least one of a detergent, antioxidant, metal deactivator, foam inhibitor, seal swell agent, and viscosity modifier.