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(54) **Oxidation stable gear oil compositions**

(57) A gear oil lubricant composition and method of operating a vehicle with the composition. The composition may include a first olefinic lubricant having a viscosity ranging from about 80 centistokes to about 150 centistokes at 100 °C and a second olefinic lubricant having a viscosity ranging from about 2 centistokes to about 15 centistokes at 100 °C. A ratio of the first olefinic lubricant to the second olefinic lubricant may range from about 2:1 to about 8:1. Additionally, the composition may include an alkylated naphthalene base oil, a boronated ashless

dispersant, at least one hindered phenol antioxidant, at least one alkylated diphenylamine antioxidant, and a gear oil additive package, the composition having an active phosphorus content of less than about 700 ppm and an active sulfur content of less than about 3 wt. %. The gear oil lubricant composition may contain less than about 0.1 percent by weight antioxidant composition based on a total weight of the lubricant composition.

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Description**FIELD**

- 5 **[0001]** The present disclosure relates to gear oil compositions, and in particular to gear oil compositions for severe duty applications that exhibit improved oxidation stability for extended periods of time.

BACKGROUND

- 10 **[0002]** Lubricants are used to reduce wear between moving parts where there is metal to metal contact and to remove heat from the parts. In some applications, such as the axles of heavy duty vehicles, the lubricants may encounter extreme temperatures in an environment in which they are used. Extreme temperatures and applied loads may result in increased oxidation of the lubricants thereby increasing the viscosity of the lubricants above a desirable level. As the viscosity increases, the lubricity properties of the lubricants may significantly decrease to the point of axle failure.
- 15 **[0003]** Accordingly, for severe duty applications where environmental temperatures may exceed about 40 °C for extended periods of time and where the vehicle load may exceed 25 metric tons, axle lubricants must be changed more often than lubricants used in less harsh environments. If the lubricants are not changed on a more frequent schedule, damage to moving parts relying on lubrication may occur. Until now, lubricants for heavy duty applications, such as GL-5 gear oils, must pass an oxidation stability test according to an ASTM D5704 (L60-1) that is a 50 hour test. However,
- 20 such evaluation does not provide lubricants that are suitable for the severe duties described above. Accordingly, what is needed is a lubricant for heavy duty applications that can pass an L60-1 oxidation stability test of about 300 hours in order to provide lubricant replacement intervals of significantly greater than about 30,000 kilometers in a severe environment.

SUMMARY OF THE EMBODIMENTS

- 25 **[0004]** With regard to the foregoing, the disclosure provides a gear oil lubricant composition including a first olefinic lubricant having a viscosity ranging from about 80 centistokes to about 150 centistokes at 100 °C and a second olefinic lubricant having a viscosity ranging from about 2 centistokes to about 15 centistokes at 100 °C. A ratio of the first olefinic lubricant to the second olefinic lubricant ranges from about 2:1 to about 8:1. Additionally, the composition may include
- 30 an alkylated naphthalene base oil, a boronated ashless dispersant, at least one hindered phenol antioxidant, at least one alkylated diphenylamine antioxidant, and a gear oil additive package having an active phosphorus content of less than about 700 ppm and an active sulfur content of less than about 2 weight percent. The gear oil lubricant composition may contain less than about 0.1 percent by weight antioxidant composition based on a total weight of the lubricant composition.

- 35 **[0005]** The invention also provides a gear oil lubricant composition comprising:
- a first olefinic lubricant having a viscosity ranging from about 80 centistokes to about 150 centistokes at 100 °C;
- 40 a second olefinic lubricant having a viscosity ranging from about 2 centistokes to about 15 centistokes at 100 °C, wherein a ratio of the first olefinic lubricant to the second olefinic lubricant ranges from about 2:1 to about 8:1;
- an alkylated naphthalene base oil;
- a boronated ashless dispersant;
- an antioxidant composition comprising at least one hindered phenol antioxidant and at least one alkylated diphenylamine antioxidant; and
- 45 a gear oil additive package,
- wherein the gear oil lubricant composition contains less than about 0.1 percent by weight antioxidant composition based on a total lubricant composition, and has an active phosphorus content of less than about 700 ppm and an active sulfur content of up to about 3 wt.%.

- 50 **[0006]** In another embodiment there is provided a thermally stable gear oil lubricant composition. The lubricant composition includes a first olefinic lubricant having a viscosity ranging from about 80 centistokes to about 150 centistokes at 100 °C, and a second olefinic lubricant having a viscosity ranging from about 2 centistokes to about 15 centistokes at 100 °C. A ratio of the first polyolefinic lubricant to the second olefinic lubricant ranges from about 2:1 to about 8:1. Also included in the composition may be an alkylated naphthalene base oil, a boronated ashless dispersant, an antioxidant composition comprising at least one hindered phenol antioxidant and at least one alkylated diphenylamine antioxidant;
- 55 and a conventional gear oil additive package. With respect thermal stability, the lubricant composition may have a carbon varnish rating of greater than about 7.5 and a sludge rating of about 9.4 after an L60-oxidative stability test of 300 hours.
- [0007]** In a further embodiment there is provided a heavy duty gear oil lubricant composition comprising:

a first olefinic lubricant having a viscosity ranging from about 80 centistokes to about 150 centistokes at 100 °C;
 a second olefinic lubricant having a viscosity ranging from about 2 centistokes to about 15 centistokes at 100 °C,
 wherein a ratio of the first olefinic lubricant to the second olefinic lubricant ranges from about 2:1 to about 8:1;
 an alkylated naphthalene based oil;
 a boronated ashless dispersant;
 an antioxidant composition comprising at least one hindered phenol antioxidant and at least one alkylated diphenylamine antioxidant; and
 a conventional gear oil additive package;
 wherein the gear oil lubricant composition has a reactive amine content of less than about 100 to about 400 ppm
 based on an active nitrogen content of the lubricant composition.

[0008] In yet another embodiment there is provided a method of operating a vehicle containing a drive axle. The method includes providing as a lubricant for the drive axle a composition containing a first olefinic lubricant having a viscosity ranging from about 80 centistokes to about 150 centistokes at 100 °C and a second olefinic lubricant having a viscosity ranging from about 2 centistokes to about 15 centistokes at 100 °C. A ratio of the first olefinic lubricant to the second olefinic lubricant ranges from about 2:1 to about 8:1. The composition may also include an alkylated naphthalene base oil, a boronated ashless dispersant, an antioxidant composition comprising at least one hindered phenol antioxidant and at least one alkylated diphenylamine antioxidant, and a conventional gear oil additive package. The lubricant composition may have an oxidation stability in a 300 hour oxidation stability test that provides a viscosity increase of less than about 100%, a carbon varnish rating of greater than about 7.4, and a sludge rating of greater than or equal to about 9.3.

[0009] An advantage of compositions according to the disclosure is that heavy duty gear applications using the lubricants exhibit reduce wear and/or failure without decreasing the lubricant replacement interval. Another advantage is that the lubricant compositions according to the disclosure may be formulated from commercially available components. The following detailed description of embodiments may provide other advantages.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group having a carbon atom directly attached to the remainder of a molecule and having a predominantly hydrocarbon character. Examples of hydrocarbyl groups include:

- (1) hydrocarbon substituents, that is, aliphatic (e.g., alkyl or alkenyl), alicyclic (e.g., cycloalkyl, cycloalkenyl) substituents, and aromatic-, aliphatic-, and alicyclic-substituted aromatic substituents, as well as cyclic substituents wherein the ring is completed through another portion of the molecule (e.g., two substituents together form an alicyclic radical);
- (2) substituted hydrocarbon substituents, that is, substituents containing non-hydrocarbon groups which, in the context of the description herein, do not alter the predominantly hydrocarbon substituent (e.g., halo (especially chloro and fluoro), hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulfoxy);
- (3) hetero-substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this description, contain other than carbon in a ring or chain otherwise composed of carbon atoms. Hetero-atoms include sulfur, oxygen, nitrogen, and encompass substituents such as pyridyl, furyl, thienyl, and imidazolyl. In general, no more than two, such as no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group; typically, there will be one non-hydrocarbon substituent in the hydrocarbyl group.

[0011] Lubricant compositions according to the disclosure contain a base oil component, an antioxidant composition, an ashless dispersant, and a gear oil additive package. The compositions may be characterized by having an active sulfur content of up to about 3 wt.%, for example less than about 2.5 wt.% or from about 1 wt.% to about 3 wt.%, an active phosphorus content of less than about 700 ppm for example from about 200 to about 700 ppm, and an active nitrogen content of from about 100 to about 700 ppm, typically from about 300 to about 500 ppm. Preferably the lubricant compositions have a reactive amine content of from about 100 to about 400 ppm based on an active nitrogen content of the lubricant composition. The lubricant composition may also be characterized by having a carbon varnish rating of greater than about 7.4 and a sludge rating of greater than about 9.3 after a 300 hour oxidation stability test conducted according to ASTM D5704 (L60-1).

Base Oil Component

[0012] The base oil component of lubricant compositions according to the disclosure may include an α -olefin component and a Group V base oil component. Oligomerized α -olefins have been known for many years to be effective synthetic

lubricating oils. For example, U.S. Pat. No. 3,149,178 to Hamilton et al., describes oligomers of C₆₋₁₂ α -olefins made using a Friedel-Crafts catalyst, a peroxide catalyst or thermal treatment. The starting olefins are predominantly α -olefins, that is, linear terminal olefins. By predominantly is meant that they contain over about 50 mole percent, as a further example, over about 75 mole percent of α -olefins.

[0013] It is desirable to use pure α -olefins in the base oil component, but commercially available α -olefins contain minor amounts of internal olefins and vinylidene olefins. It has been found that in making dimmers, fairly large amounts of internal olefins can be tolerated without adversely affecting the physical properties of the oligomer. It would appear that either the α -olefins in the commercial olefins can react with the internal olefins or that the internal olefins are in equilibrium with α -olefins and that as the α -olefins react, more internal olefins are isomerized to α -olefins.

[0014] Suitable olefinic oligomers for use as a base oil include hydrogenated olefin oligomers consisting mainly of dimers of C₆₋₂₀ predominantly α -olefins having a viscosity above about 3.0 centistokes (cSt) at 100 °C. Such oligomers may be made by contacting a C₆₋₂₀ predominantly α -olefin or mixture thereof with a Friedel-Crafts catalyst at a temperature of about 20 °C to about 200 °C until the reaction mixture excluding monomer is predominantly dimer. Representative Friedel-Crafts catalysts are BF₃, BCl₃, AlCl₃, AlBr₃, SnCl₄, GaCl₃, and the like. The product is distilled to remove unreacted monomer and then is hydrogenated.

[0015] Accordingly, olefins which may be used for making the oligomers are dodecene, tridecene, tetradecene, pentadecene, hexadecene, heptadecene, and octadecene. When dodecene is used it should be in a mixture of olefins containing higher olefins, e.g. tetradecene, hexadecane, and the like. Other suitable olefins used as starting materials contain about 12 to about 16 carbon atoms and mixtures thereof with the above stated proviso regarding dodecene.

[0016] A relatively low viscosity α -olefin oligomer and a relatively high viscosity α -olefin oligomer make up a predominant amount of the base oil component. By predominant amount is meant that the base oil contains over 50 percent by weight of the low and high viscosity α -olefin oligomers. The α -olefin oligomer having the highest viscosity has a kinematic viscosity at 100 °C of about 80 to about 120 cSt. The relatively low viscosity α -olefin oligomer has a kinematic viscosity at 100 °C of about 6 to about 10 cSt. A weight ratio of the high viscosity α -olefin oligomer to the low viscosity α -olefin oligomer in the lubricant composition typically ranges from about 2:1 to about 6:1.

[0017] An important component of lubricant compositions according to the disclosure is a Group V base oil as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. A suitable Group V component is an alkylated aromatic compound. Suitable alkylated aromatic compounds include alkylated benzenes, alkylated anthracenes, alkylated phenanthrenes, alkylated biphenyls, and alkylated naphthalenes and the like.

[0018] Alkylated naphthalenes may be produced by any suitable means known in the art, from naphthalene itself or from substituted naphthalenes which may contain one or more short chain alkyl groups having up to about eight carbon atoms, such as methyl, ethyl, or propyl, etc. Suitable alkyl-substituted naphthalenes include alphas-methylnaphthalene, dimethylnaphthalene, and ethylnaphthalene. Naphthalene itself is suitable since the resulting mono-alkylated products have better thermal and oxidative stability than the more highly alkylated materials. Alkylated naphthalene lubricant compositions are described in U.S. Patent No. 3,812,036 to Romine and U.S. Patent No. 5,602,086 to Le et al. The production of alkylnaphthalenes is disclosed in U.S. Pat. No. 4,714,794 to Yoshida et al. A commercially available alkylated naphthalene is available from Exxon/Mobil Chemical Company of Houston, Texas under the trade name SYNESSTIC® 12.

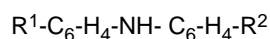
[0019] The amount of alkylated naphthalene component in the lubricant composition may range from about 20 to about 35 percent by weight of the total weight of the composition. With respect to the α -olefin oligomer components, the alkylated naphthalene component is present in a ratio of α -olefin oligomers to alkylated naphthalene ranging from about 1.5:1 to about 2.5:1.

Antioxidant Component

[0020] The antioxidant component of the lubricant compositions includes at least two antioxidant compounds, i.e., a hindered phenol antioxidant and an aromatic amine antioxidant. Illustrative examples of sterically hindered phenolic antioxidants include orthoalkylated phenolic compounds such as 2,6-di-tert-butylphenol, 4-methyl-2,6-di-tert-butylphenol, 2,4,6-tri-tert-butylphenol, 2-tert-butylphenol, 2,6-diisopropylphenol, 2-methyl-6-tert-butylphenol, 2,4-dimethyl-6-tert-butylphenol, 4-(N,N-dimethylaminomethyl)-2,8-di-tert-butylphenol, 4-ethyl-2,6-di-tert-butylphenol, 2-methyl-6-styrylphenol, 2,6-distyryl-4-nonylphenol, and their analogs and homologs. Mixtures of two or more of the foregoing phenolic compounds are also be used as the first antioxidant compound.

[0021] Aromatic amine antioxidant compounds include aromatic secondary monoamines and aromatic secondary polyamines. Illustrative aromatic secondary monoamines include diphenylamine, alkyl diphenylamines containing 1 or 2 alkyl substituents each having up to about 16 carbon atoms, phenyl-t-naphthylamine, phenyl- β -naphthylamine, alkyl- or aralkylsubstituted phenyl- β -naphthylamine containing one or two alkyl or aralkyl groups each having up to about 16 carbon atoms, alkyl- or aralkylsubstituted phenyl-p-naphthylamine containing one or two alkyl or aralkyl groups each having up to about 16 carbon atoms, and similar compounds.

[0022] A suitable type of aromatic amine antioxidant is an alkylated diphenylamine of the general formula:



wherein R^1 is an alkyl group (for example, a branched alkyl group) having about 8 to about 12 carbon atoms (as another example, about 8 or about 9 carbon atoms) and R^2 is a hydrogen atom, alkylaryl or an alkyl group (such as a branched alkyl group) having about 8 to about 12 carbon atoms, (as another example, about 8 or about 9 carbon atoms). Suitable compounds are available commercially from Crompton Corporation of Middlebury, Connecticut under the trade names NAUGALUBE® 438L, 640, and 680. Other commercially available aromatic amine antioxidants include compounds available from R. T. Vanderbilt Company, Inc. of Norwalk, Connecticut under the trade names VANLUBE® SL, DND, NA, 81, 961, and 2005.

[0023] The amount of antioxidant component in lubricant compositions described herein may be less than about 0.5 percent by weight of the total weight of lubricant composition. Typically, the antioxidant component may range from about 0.05 to about 0.25 weight percent based on the total weight of the lubricant composition. Of the total amount of antioxidant component, the hindered phenolic antioxidant may be present in an amount that ranges from about 0.70 to about 1.30 times the amount of aromatic amine antioxidant in the lubricant composition. A suitable antioxidant may contain about 50 wt. % hindered phenolic antioxidant and 50 wt. % aromatic amine antioxidant.

Ashless Dispersant component

[0024] The ashless dispersant of the lubricant compositions described herein may be selected from any of the ashless dispersants known to those skilled in the art. A suitable ashless dispersant is a hydrocarbyl-substituted succinimide dispersant which is post-treated to provide a boronated or boronated/phosphorylated dispersant.

[0025] Hydrocarbyl-substituted succinic acylating agents are used to make hydrocarbyl-substituted succinimides. The hydrocarbyl-substituted succinic acylating agents include, but are not limited to, hydrocarbyl-substituted succinic acids, hydrocarbyl-substituted succinic anhydrides, the hydrocarbyl-substituted succinic acid halides (especially the acid fluorides and acid chlorides), and the esters of the hydrocarbyl-substituted succinic acids and lower alcohols (e.g., those containing up to about 7 carbon atoms), that is, hydrocarbyl-substituted compounds which can function as carboxylic acylating agents.

[0026] Hydrocarbyl substituted acylating agents are made as by reacting a polyolefin or chlorinated polyolefin of appropriate molecular weight with maleic anhydride. Similar carboxylic reactants can be used to make the acylating agents. Such reactants may include, but are not limited to, maleic acid, fumaric acid, malic acid, tartaric acid, itaconic acid, itaconic anhydride, citraconic acid, citraconic anhydride, mesaconic acid, ethylmaleic anhydride, dimethylmaleic anhydride, ethylmaleic acid, dimethylmaleic acid, hexylmaleic acid, and the like, including the corresponding acid halides and lower aliphatic esters.

[0027] Hydrocarbyl-substituted succinic anhydrides are conventionally prepared by heating a mixture of maleic anhydride and an aliphatic olefin at a temperature of from about 175 °C to about 275 °C. The molecular weight of the olefin can vary depending upon the intended use of the substituted succinic anhydrides. Typically, the substituted succinic anhydrides will have a hydrocarbyl group of from about 8-500 carbon atoms. However, substituted succinic anhydrides used to make lubricating oil dispersants will typically have a hydrocarbyl group of about 40-500 carbon atoms. Dispersants having a hydrocarbyl group containing from about 8 to about 150 carbon atoms are referred to herein as "relatively low molecular weight dispersants." Whereas dispersants having a hydrocarbyl group containing more than about 150 carbon atoms up to about 500 carbon atoms are referred to herein as "relatively high molecular weight dispersants." With the very high molecular weight substituted succinic anhydrides, it is more accurate to refer to number average molecular weight (M_n) since the olefins used to make these substituted succinic anhydrides may include a mixture of different molecular weight components resulting from the polymerization of low molecular weight olefin monomers such as ethylene, propylene and isobutylene.

[0028] The mole ratio of maleic anhydride to olefin can vary widely. It may vary, for example, from about 5:1 to about 1:5, as another example, from about 1:1 to about 3:1. With olefins such as polyisobutylene having a number average molecular weight of about 500 to about 7000, as a further example about 800 to about 3000 or higher and the ethylene-alpha-olefin copolymers, the maleic anhydride may be used in stoichiometric excess, e.g. about 1.1 to about 3 moles maleic anhydride per mole of olefin. The unreacted maleic anhydride can be vaporized from the resultant reaction mixture.

[0029] The hydrocarbyl-substituted succinic anhydrides include polyalkyl or polyalkenyl succinic anhydrides prepared by the reaction of maleic anhydride with the desired polyolefin or chlorinated polyolefin, under reaction conditions well known in the art. For example, such succinic anhydrides may be prepared by the thermal reaction of a polyolefin and maleic anhydride, as described in U.S. Pat. Nos. 3,361,673; 3,676,089; and 5,454,964. Alternatively, the substituted succinic anhydrides can be prepared by the reaction of chlorinated polyolefins with maleic anhydride, as described, for example, in U.S. Pat. No. 3,172,892. A further discussion of hydrocarbyl-substituted succinic anhydrides can be found,

for example, in U.S. Pat. Nos. 4,234,435; 5,620,486 and 5,393,309. Typically, these hydrocarbyl-substituents will contain from about 40 to about 500 carbon atoms.

[0030] Polyalkenyl succinic anhydrides may be converted to polyalkyl succinic anhydrides by using conventional reducing conditions such as catalytic hydrogenation. For catalytic hydrogenation, a suitable catalyst is palladium on carbon. Likewise, polyalkenyl succinimides may be converted to polyalkyl succinimides using similar reducing conditions.

[0031] The polyalkyl or polyalkenyl substituent on the succinic anhydrides employed herein is generally derived from polyolefins which are polymers or copolymers of mono-olefins, particularly 1-mono-olefins, such as ethylene, propylene, and butylene. For example, the mono-olefin employed will have about 2 to about 24 carbon atoms, and as a further example, about 3 to about 12 carbon atoms. Suitable mono-olefins include propylene, butylene, particularly isobutylene, 1-octene, and 1-decene. Polyolefins prepared from such mono-olefins include polypropylene, polybutene, polyisobutene, and the polyalphaolefins produced from 1-octene and 1-decene.

[0032] In some embodiments, the ashless dispersant may include one or more alkenyl succinimides of an amine having at least one primary amino group capable of forming an imide group. The alkenyl succinimides may be formed by conventional methods such as by heating an alkenyl succinic anhydride, acid, acid-ester, acid halide, or lower alkyl ester with an amine containing at least one primary amino group. The alkenyl succinic anhydride may be made readily by heating a mixture of polyolefin and maleic anhydride to about 180 °C to about 220 °C. The polyolefin may be a polymer or copolymer of a lower monoolefin such as ethylene, propylene, isobutene, and the like, having a number average molecular weight in the range of about 900 to about 3000 as determined by gel permeation chromatography (GPC).

[0033] Amines which may be employed in forming the ashless dispersant include any that have at least one primary amino group which can react to form an imide group and at least one additional primary or secondary amino group and/or at least one hydroxyl group. A few representative examples are: N-methyl-propanediamine, N-dodecylpropanediamine, N-aminopropyl-piperazine, ethanolamine, N-ethanol-ethylenediamine, and the like.

[0034] Boronated dispersants may be formed by boronating (borating) an ashless dispersant having basic nitrogen in the molecule. The boronated dispersant may contain at least one polyalkylene moiety. As a further example, the boronated dispersant may include at least two polyalkylene moieties. The polyalkylene moiety may have a molecular weight of from about 900 weight average molecular weight to about 3000 weight average molecular weight. The polyalkylene moiety, for example, may have a molecular weight of from about 1300 weight average molecular weight to about 2100 weight average molecular weight. As a further example, the polyalkylene moiety may have a molecular weight of about 2100 weight average molecular weight. The polyalkylene moiety may include a polybutenyl group. Methods that can be used for boronating the various types of ashless dispersants described above are described for example in U.S. Pat. Nos. 3,087,936; 3,254,025; 3,281,428; 3,282,955; 2,284,409; 2,284,410; 3,338,832; 3,344,069; 3,533,945; 3,658,836; 3,703,536; 3,718,663; 4,455,243; and 4,652,387.

[0035] The boronated dispersant may include a high molecular weight dispersant treated with boron such that the borated dispersant includes up to about 1 wt. % of boron. As another example the boronated dispersant may include from about 0.7 wt% or less of boron. As a further example, the borated dispersant may include from about 0.1 to about 0.7 wt% of boron. As an even further example, the boronated dispersant may include from about 0.25 to about 0.7 wt% of boron. As a further example, the boronated dispersant may include from about 0.35 to about 0.7 wt% of boron. The dispersant may be dissolved in oil of suitable viscosity for ease of handling. It should be understood that the weight percentages given here are for neat dispersant, without any diluent oil added.

[0036] The boronated dispersant may be further reacted with an organic acid, an anhydride, and/or an aldehyde/phenol mixture. Such a process may enhance compatibility with elastomer seals, for example. The boronated dispersant may further include a mixture of boronated dispersants. As a further example, the boronated dispersant may include a nitrogen-containing dispersant and/or may be free of phosphorus.

[0037] The boronated dispersant may be present in the lubricant composition in an amount of about 1 wt. % to about 5 wt. %. Further, the fluid may include from about 1.25 wt% to about 3 wt% of the borated dispersant. Further, the fluid may include from about 1.5 wt% to about 2.5 wt% of the boronated dispersant. Further, the lubricant composition may include an amount of the boronated dispersant sufficient to provide up to 250 parts per million (ppm) by weight of boron in the finished composition, such as for example, from about 50 to about 250 ppm by weight of boron in the finished composition.

[0038] Phosphorylated dispersants may be formed by treating an ashless dispersant with an inorganic phosphorus acid or anhydride. Useful phosphorus acids or anhydrides which may be useful in forming the post-treated ashless dispersant include phosphorous acid (H_3PO_3), phosphoric acid, hypophosphoric acid, phosphorus trioxide (P_2O_3), phosphorus tetraoxide (P_2O_4), and phosphoric anhydride (P_2O_5). Mixtures of two or more such compounds can be used. Illustrative examples of dihydrocarbyl hydrogen phosphites which may be reacted with the basic nitrogen-containing dispersants for the purposes of this invention, include diethyl hydrogen phosphite, dibutyl hydrogen phosphite, di-2-ethylhexyl hydrogen phosphite, didecyl hydrogen phosphite, dicyclohexyl hydrogen phosphite, diphenyl hydrogen phosphite, isopropyl octyl hydrogen phosphite, ditetradecyl hydrogen phosphite, dibenzyl hydrogen phosphite, and the like. Normally the hydrocarbyl groups will each contain up to about 30 carbon atoms. Mixtures of two or more such phosphites

can be employed. Dibutyl hydrogen phosphite is a suitable dihydrocarbyl phosphite. Among the monohydrocarbyl-phosphites which can be utilized in the practice of this invention include such compounds as monomethyl phosphite, monoethyl phosphite, monobutyl phosphite, monohexyl phosphite, monocresyl phosphite, monobenzyl phosphite, monoallyl phosphite, and the like, and mixtures of two or more such compounds. The hydrocarbyl group will normally contain up to about 30 carbon atoms. Mixtures of monohydrocarbyl and dihydrocarbyl phosphites are also suitable, as are the trihydrocarbyl phosphites and the sulfur analogs of the foregoing phosphites. Phosphorylated ashless dispersants are described for example in U.S. Patent No. 5,171,466.

[0039] The ashless dispersant component may also be glycolated by reacting a succinimide with glycolic acid as described in U.S. Patent No. 5,235,067.

[0040] A particularly suitable ashless dispersant is available from Afton Chemical Corporation of Richmond, Virginia under the trade name HiTEC® 637.

Gear Oil Additive Package Component

[0041] Another component of the gear oil lubricant composition according to the disclosure is a gear oil additive package. The gear additive package typically contains one or more of the following additives: corrosion inhibitors, extreme pressure additives, anti-wear additives, rust inhibitors, defoamers, and a process oil. The gear additive package may be, although it does not have to be, a fully-formulated gear additive package, such as a package meeting the requirements for API GL-5 and/or API MT-1 and/or MIL-PRF-2105E and/or AGMA 9005-D94. The type and amount of the components present in the gear additive package will depend on the intended final use of the product. The gear additive package is typically present in an amount of from about 2 to about 25 weight percent, based on the total weight of the lubricant composition.

[0042] A suitable gear oil additive package is available from Afton Chemical Corporation under the trade name HiTEC® 340.

Extreme Pressure Agent

[0043] Various types of sulfur-containing extreme pressure agents may be used in the gear oil additive package. Examples include dihydrocarbyl polysulfides; sulfurized olefins; sulfurized fatty acid esters of both natural and synthetic origins; trithiones; sulfurized thienyl derivatives; sulfurized terpenes; sulfurized oligomers of C₂-C₈ monoolefins; and sulfurized Diels-Alder adducts such as those disclosed in U.S. reissue patent Re 27,331. Specific examples include sulfurized polyisobutene, sulfurized isobutylene, sulfurized diisobutylene, sulfurized triisobutylene, dicyclohexyl polysulfide, diphenyl polysulfide, dibenzyl polysulfide, dinonyl polysulfide, and mixtures of di-tert-butyl polysulfide such as mixtures of di-tert-butyl trisulfide, di-tert-butyl tetrasulfide and di-tert-butyl pentasulfide, among others. Combinations of such categories of sulfur-containing extreme pressure agents can also be used, such as a combination of sulfurized isobutylene and di-tert-butyl trisulfide, a combination of sulfurized isobutylene and dinonyl trisulfide, a combination of sulfurized tall oil and dibenzyl polysulfide. The amount of extreme pressure agent in the gear oil additive package may range from about 75 to about 95 percent by weight of the total weight of the additive package. In terms of active sulfur content in the lubricant compositions, the lubricant composition may contain from about 1 wt.% to about 3 wt.% active sulfur.

Antiwear Agents

[0044] The antiwear agents may be phosphorus-containing antiwear agents which may include an organic ester of phosphoric acid, phosphorous acid, or an amine salt thereof. For example, the phosphorus-containing antiwear agent may include one or more of a dihydrocarbyl phosphite, a trihydrocarbyl phosphite, a dihydrocarbyl phosphate, a trihydrocarbyl phosphate, any sulfur analogs thereof, and any amine salts thereof. As a further example, the phosphorus-containing antiwear agent may include at least one of dibutyl hydrogen phosphite (such as HiTEC® 528 antiwear agent available from Afton Chemical Corporation of Richmond, Virginia) and an amine salt of sulfurized dibutyl hydrogen phosphite (such as HiTEC® 833 antiwear agent available from Afton Chemical Corporation).

[0045] The phosphorus-containing antiwear agent may be present in an amount sufficient to provide about 200 to about 700 parts per million by weight of phosphorus in the lubricant composition. As a further example, the phosphorus-containing antiwear agent may be present in an amount sufficient to provide about 150 to about 450 parts per million by weight of phosphorus in the lubricant composition.

[0046] The gear oil additive package component may include from about 1 wt% to about 10 wt% of the phosphorus-containing antiwear agent. As a further example, the gear oil additive package component may include from about 3 wt% to about 8 wt% of the phosphorus-containing antiwear agent. As an example, the gear oil additive package may include from about 4.5 wt% to about 5.5 wt % of an amyl acid phosphate.

Corrosion inhibitors

[0047] Copper corrosion inhibitors used in the gear oil additive package may include thiazoles, triazoles, and thiadiazoles. Examples include benzotriazole, tolyltriazole, octyltriazole, decyltriazole, dodecyltriazole, 2-mercaptobenzothiazole, 2,5-dimercapto-1,3,4-thiadiazole, 2-mercapto-5-hydrocarbylthio-1,3,4-thiadiazoles, 2-mercapto-5-hydrocarbyldithio-1,3,4-thiadiazoles, 2,5-bis(hydrocarbylthio)-1,3,4-thiadiazoles, and 2,5-bis-(hydrocarbyldithio)-1,3,4-thiadiazoles. Suitable compounds include the 1,3,4-thiadiazoles, especially the 2-hydrocarbyldithio-5-mercapto-1,3,4-dithiadiazoles and the 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazoles, a number of which are available as articles of commerce. Other suitable inhibitors of copper corrosion include ether amines; polyethoxylated compounds such as ethoxylated amines, ethoxylated phenols, and ethoxylated alcohols; imidazolines; and the like. See, for example, U.S. Patent Nos. 3,663,561 and 4,097,387. Concentrations of up to about 5 wt. % in the gear oil additive package component are typical. Suitable copper corrosion inhibitors include ashless dialkyl thiadiazoles. One example of a commercially available ashless dialkyl thiadiazole is HiTEC® 4313 corrosion inhibitor, available from Afton Chemical Corporation.

Rust Inhibitors

[0048] Rust inhibitors are another inhibitor additive typically included in the gear oil additive package. Such materials include monocarboxylic acids and polycarboxylic acids. Examples of suitable monocarboxylic acids are octanoic acid, decanoic acid and dodecanoic acid. Suitable polycarboxylic acids include dimer and trimer acids such as are produced from such acids as tall oil fatty acids, oleic acid, linoleic acid, or the like. Products of this type are currently available from various commercial sources, such as, for example, the dimer and trimer acids sold under the HYSTRENE trademark by the Humko Chemical Division of Witco Chemical Corporation and under the EMPOL trademark by Henkel Corporation.

[0049] Another useful type of rust inhibitor which may be used is comprised of the alkenyl succinic acid and alkenyl succinic anhydride corrosion inhibitors such as, for example, tetrapropenylsuccinic acid, tetrapropenylsuccinic anhydride, tetradecenylsuccinic acid, tetradecenylsuccinic anhydride, hexadecenylsuccinic acid, hexadecenylsuccinic anhydride, and the like. Also useful are the half esters of alkenyl succinic acids having about 8 to about 24 carbon atoms in the alkenyl group with alcohols such as the polyglycols.

[0050] Still other suitable rust inhibitors include ether amines; acid phosphates; amines; polyethoxylated compounds such as ethoxylated amines, ethoxylated phenols, and ethoxylated alcohols; imidazolines; aminosuccinic acids or derivatives thereof, and the like. Materials of these types are available as articles of commerce. Mixtures of such rust inhibitors may be used. The amount of rust inhibitor in the gear oil additive package component may range from about 2 to about 8 weight percent based on the total weight of the gear oil additive package.

Antifoam agents

[0051] A foam inhibitor forms another component of the gear oil additive package. Foam inhibitors may be selected from silicones, polyacrylates, surfactants, and the like. One suitable acrylic defoamer material is PC-2244 available from Monsanto Company. The amount of antifoam agent in the gear oil additive package may range from about 0.5 to about 2.0 weight percent based on the total weight of the gear oil additive package.

Process Oil

[0052] The process oil used in the gear oil additive package may be a natural oil, a mineral oil, or a blend of such oils. The oil can be paraffinic, naphthenic, or a blend of mineral oils. Pursuant to an embodiment, the process oil is a 60 Neutral mineral oil. The process oil is present in the gear oil additive package in an amount sufficient to solubilize the components of the additive package. Typically, the additive package will contain from about 2 to about 10 percent by weight of the process oil.

[0053] The following non-limiting example is given to illustrate aspects of the disclosed embodiments. The example is not intended to limit the embodiments as disclosed herein.

Example

[0054] A gear oil lubricant (Sample 1) was formulated as follows:

| Component | Weight Percent |
|--------------------------------|----------------|
| 8 cSt polyalphaolefin base oil | 11.59 |

Table continued

| Component | Weight Percent |
|-------------------------------------|----------------|
| 100 cSt polyalphaolefin base oil | 47.00 |
| alkylated naphthalene base oil | 28.00 |
| seal swell agent | 8.00 |
| gear oil additive package | 4.00 |
| boronated ashless dispersant | 1.31 |
| hindered phenol antioxidant | 0.03 |
| alkylated diphenylamine antioxidant | 0.03 |
| Process oil | 0.04 |

[0055] The above gear oil formulation had a viscosity grade of 80W-140, and was tested 300 hours for thermal and oxidative stability according to the ASTM D 5704 (L-60-1) using the SAE J2360 procedure. The results are given in the following table.

| | SAE J2360 | Sample 1 |
|-----------------------------------|-----------|-----------|
| Oxidation Stability Test (L-60-1) | 50 hours | 300 hours |
| Viscosity Rise (%) | 100 Max. | 89.24 |
| Pentane Insolubles (wt.%) | 3.0 Max. | - 0.86 |
| Toluene Insolubles (wt. %) | 2.0 Max. | 0.06 |
| Carbon Varnish (Rating) | 7.5 Min. | 8.30 |
| Sludge (Rating) | 9.4 Min. | 9.47 |

[0056] From the foregoing table, it is evident that a gear oil lubricant according to the disclosed embodiments may provide superior performance in harsh environments as it is able to provide a relatively low viscosity increase, and relatively high sludge and carbon varnish ratings over extended periods of time. It is expected that a gear oil formulation as disclosed herein will provide extended drain intervals without causing excessive wear of vehicle components such as axles.

[0057] At numerous places throughout this specification, reference has been made to a number of U.S. Patents. All such cited documents are expressly incorporated in full into this disclosure as if fully set forth herein.

[0058] Other embodiments of the present invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. As used throughout the specification and claims, "a" and/or "an" may refer to one or more than one. Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, percent, ratio, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

Claims

1. A gear oil lubricant composition comprising:

a first olefinic lubricant having a viscosity ranging from about 80 centistokes to about 150 centistokes at 100 °C;
a second olefinic lubricant having a viscosity ranging from about 2 centistokes to about 15 centistokes at 100 °C, wherein a ratio of the first olefinic lubricant to the second olefinic lubricant ranges from about 2:1 to about 8:1;
an alkylated naphthalene base oil;
a boronated ashless dispersant;
an antioxidant composition comprising at least one hindered phenol antioxidant and at least one alkylated diphenylamine antioxidant; and
a gear oil additive package,
wherein the gear oil lubricant composition contains less than about 0.1 percent by weight antioxidant composition based on a total lubricant composition, and has an active phosphorus content of less than about 700 ppm and an active sulfur content of up to about 3 wt.%.

2. The gear oil lubricant composition of claim 1, wherein the gear oil additive package comprises an extreme pressure agent, an antiwear agent, a rust inhibitor, a corrosion inhibitor, a defoamer, and a process oil.
3. The gear oil lubricant composition of claim 1 or claim 2, further comprising a seal swelling agent.
4. The gear oil lubricant composition of any one of claims 1 to 3, wherein the composition contains from about 100 to about 700 ppm active nitrogen atoms.
5. The gear oil lubricant composition of any one of claims 1 to 4, wherein the ashless dispersant comprises a hydrocarbyl substituted succinimide.
6. The gear oil lubricant composition of claim 5, wherein the ashless dispersant comprises a boronated/phosphorylated ashless dispersant.
7. The gear oil lubricant composition of any one of the preceding claims, wherein the first and second olefinic lubricant comprises oligomers of alphaolefins.
8. The gear oil lubricant composition of any one of the preceding claims wherein the gear oil lubricant composition has a reactive amine content of from about 100 to about 400 ppm based on an active nitrogen content of the lubricant composition.
9. The gear oil lubricant composition of any one of the preceding claims, wherein the composition has an active sulfur content ranging from about 1 wt.% to about 3 wt.% and an active phosphorus content ranging from about 250 to about 700 ppm.
10. The gear oil lubricant composition according to any one of the preceding claims, wherein, with respect to thermal stability, the lubricant composition has a carbon varnish rating of greater than about 7.4 and a sludge rating of greater than about 9.3 after an L60-1 oxidative stability test of about 300 hours.
11. The gear oil lubricant composition of claim 10, wherein the lubricant composition has a viscosity rise of less than about 100%.
12. A vehicle axle containing the gear oil lubricant of any one of the preceding claims.
13. Use of a composition as claimed in any one of claims 1 to 11 as a lubricant for a drive axle.
14. Use as claimed in claim 13 wherein the lubricant composition has an oxidation stability in a 300 hour L60-1 oxidative stability test that provides a viscosity increase of less than about 100%, a carbon varnish rating of greater than about 7.4 and a sludge rating of greater than or equal to 9.3.
15. Use as claimed in claim 13 or claim 14 wherein the vehicle in which the drive axle is used is operated in an environment having a temperature of greater than about 40 °C.
16. Use as claimed in any one of claims 13 to 15 wherein the vehicle in which the drive axle is operated for a distance of more than about 30,000 kilometers between lubricant drain intervals.

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17. Use as claimed in any one of claims 13 to 16 wherein the axle is an axle of a heavy duty truck vehicle.

18. Use as claimed in claim 17 wherein the heavy duty truck vehicle can pull combined loads in excess of 25 metric tons.

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