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(54) LUBRICATING COMPOSITION FOR A HYBRID ELECTRIC VEHICLE TRANSMISSION

SCHMIERMITTELZUSAMMENSETZUNG FÜR GETRIEBE EINES ELEKTRISCHEN HYBRIDFAHRZEUGS

COMPOSITION LUBRIFIANTE POUR UNE TRANSMISSION DE VÉHICULE ÉLECTRIQUE HYBRIDE

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Description

BACKGROUND OF THE INVENTION

[0001] The disclosed technology relates to a lubricant composition for use in an automatic transmission of a hybrid electric vehicle, containing an oil of lubricating viscosity, at least one borate ester, and at least one phosphorus containing compound.

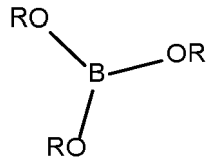
[0002] Driveline transmissions especially automatic transmission fluids (ATFs), present highly challenging technological problems and solutions for satisfying the multiple and often conflicting lubricating and power transmitting requirements of modern automatic transmissions (including continuously variable transmissions of various types). Many additive components are typically included in an ATF, providing such performance characteristics as lubrication, dispersancy, friction control (for clutches), antiwear durability (e.g., gear wear) and pump durability, fuel economy, anti-shudder performance, anti-corrosion and anti-oxidation performance. However, over periods of use, the additive components are consumed which may detrimentally damage transmissions.

[0003] On top of the normal issues, transmissions in electric vehicles, generally automatic transmissions, exhibit a unique set of issues. For example, lubricants for transmissions in electric vehicles can come into contact with electric componentry in the vehicle, such as parts of the electric motor. Thus, one attribute desirable for such lubricants is a relatively low electrical conductivity to avoid potential current leakage and case resistance, particularly as the lubricant oil ages. However, the lubricant must still provide proper lubrication, including, for example, dispersancy, cleanliness, anti-wear and anti-corrosion. Likewise, it is desirable to maintain a low viscosity fluid for such vehicles to improve the vehicle efficiency. Accordingly, new transmission fluids are needed to achieve these often competing results.

[0004] WO 2016/089565 A1 discloses mixed phosphorous esters for lubricant applications.

SUMMARY OF THE INVENTION

[0005] The disclosed technology provides a lubricant composition for lubricating a transmission in a vehicle with an electric motor comprising a. an oil of lubricating viscosity, b. 0.2 to 2.0 wt % of at least one borate ester of formula I,



wherein each R, independently, is a C_3 to C_{12} alkyl,

c. at least one phosphorous containing compound comprising a phosphite ester composition that comprises the reaction product of a monomeric phosphorous acid or an ester thereof with at least two alkylene diols, wherein the at least one phosphorus containing compound is present in an amount to deliver 100 to 450 ppm of phosphorus to the lubricating composition,

d. a dispersant at a total amount of 1.8 wt.% or less and delivering less than 100 ppm boron to the lubricant composition, wherein the dispersant is selected from the group consisting of succinimide dispersants prepared by the reaction of a hydrocarbyl-substituted succinic anhydride or reactive equivalent thereof with an amine; amine dispersants prepared by the reaction of high molecular weight aliphatic or alicyclic halides and amines; Mannich dispersants prepared by the reaction of alkyl phenols in which the alkyl group contains at least 30 carbon atoms with aldehydes and amines; ester dispersants prepared by reaction of a hydrocarbyl acylating agent and a polyhydric aliphatic alcohol; and mixtures thereof, and

e. optionally a calcium containing sulfonate or salicylate detergent or mixtures thereof present in an amount to deliver 300 ppm or less calcium to the lubricating composition,

wherein the lubricant composition has a kinematic viscosity at 40°C of from 8 cSt to 18 cSt, and wherein the ratio of phosphorous from the phosphite ester composition of (c) and the boron from the borate ester of (b) is greater than 0.7.

[0006] In embodiments, the lubricant composition can further include 0.01 to 1.0 wt % of an ester of (1) a polyol, and 2) an aliphatic carboxylic acid containing about 12 to about 24 carbon atom, such as, for example, glycerol monooleate.

[0007] In further embodiments, the lubricant composition can also include 0.1 to 3.0 wt % of an ester of (1) an alcohol, and 2) an aliphatic carboxylic acid containing about 4 to about 8 carbon atoms, such as, for example, an adipate ester.

[0008] In still further embodiments, the lubricant composition can contain 0.01 wt % to 0.5 wt % of a dimercaptothia-

diazole or derivative thereof.

[0009] The lubricant composition can also contain from 0.1 wt % to 5 wt % of a poly(meth)acrylate ester polymer viscosity modifier.

[0010] In some embodiments, the lubricant composition can additionally include 0.05 wt % to 1.0 wt % of a C_{12} to C_{24} hydrocarbyl phosphite.

[0011] The lubricant composition can also include 0.01 wt % to 1.0 wt % of a C_{12-24} borated epoxide.

[0012] The lubricant composition can also include 0.1 wt % to 3.0 wt % of a mixture of at least two antioxidants selected from hindered phenols, aryl amines, and sulfur containing antioxidants.

[0013] The lubricant composition can be employed in a method of lubricating an automatic transmission in a vehicle with an electric motor, by supplying the lubricant composition to the automatic transmission, and operating the automatic transmission.

DETAILED DESCRIPTION OF THE INVENTION

[0014] Various preferred features and embodiments will be described below by way of non-limiting illustration.

[0015] One aspect of the present technology is a lubricant composition. The lubricant composition can be employed to provide lubrication in an automatic transmission for a hybrid electric vehicle.

Oils of Lubricating Viscosity

[0016] The oil of lubricating viscosity may be defined as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. The five base oil groups are as follows: Group I (sulphur content >0.03 wt %, and/or <90 wt % saturates, viscosity index 80-120); Group II (sulphur content ≤0.03 wt %, and ≥90 wt % saturates, viscosity index 80-120); Group III (sulphur content ≤0.03 wt %, and ≥90 wt % saturates, viscosity index ≥120); Group IV (all polyalphaolefins (PAOs)); and Group V (all others not included in Groups I, II, III, or IV). The oil of lubricating viscosity can include, for example, an API Group I, Group II, Group III, Group IV, Group V oil or mixtures thereof.

[0017] Often the oil of lubricating viscosity is an API Group I, Group II, Group III, Group IV oil or mixtures thereof. Alternatively, the oil of lubricating viscosity can be an API Group II, Group III or Group IV oil or mixtures thereof.

[0018] In one embodiment the oil of lubricating viscosity may be prepared by a Fischer-Tropsch gas-to-liquid synthetic procedure as well as other gas-to-liquid oils.

[0019] In one embodiment the oil of lubricating viscosity may be an API Group IV oil. The amount of Group IV oil may be 0 wt % to 20 wt %, or 0.1 wt % to 20 wt %, or 1 wt % to 15 wt %, or 5 to 10 wt % of the lubricating composition.

[0020] The amount of the oil of lubricating viscosity present is typically the balance remaining after subtracting from 100 wt % the sum of the amount of performance additives of the present invention.

[0021] The lubricating composition may be in the form of a concentrate and/or a fully formulated lubricant. If the performance additives of this invention are in the form of a concentrate (which may be combined with additional oil to form, in whole or in part, a finished lubricant), the ratio of the performance additives to the oil of lubricating viscosity and/or to diluent oil include the ranges of 1:99 to 99:1 by weight, or 80:20 to 10:90 by weight.

Boron-Containing Compound

[0022] The lubricant composition can contain a boron-containing compound in an amount sufficient to provide from about 75ppm to about 500 ppm of boron to the lubricant composition, or from about 85 to about 450 ppm or about 95 to about 350 ppm boron, or from about 100 to about 400ppm boron to the lubricant composition.

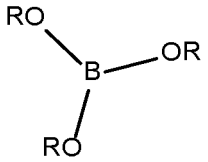
[0023] The boron can be delivered by many types of boron-containing compounds.

[0024] The boron-containing compound can be a dispersant post-treated with a source of boron. Such dispersants are generally obtained by reacting a carboxylic (e.g., succinimide), amine or Mannich dispersant with a boron compound reagent, such as boric acid (to give "borated dispersants"). Dispersants and their method of production are well-known in the art. The borated dispersant may be further functionalized with a sulfur or phosphorus moiety. The dispersant component in the borated dispersant may be a mixture of multiple dispersants which may be of different types; optionally at least one may be a succinimide dispersant. In one embodiment the borated dispersant may be a borated polyisobutylene succinimide dispersant, in which the polyisobutylene portion thereof may have a number average molecular weight of 750 to 2200, or 750 to 1350, or 750 to 1150. The borated dispersant(s) may be prepared in such a way to have a N:CO ratio of 0.9:1 to 1.6:1, or 0.95:1 to 1.5:1, or 1:1 to 1.4:1. The amount of borated dispersant in the compositions, may be, for instance, 0.05 to 2.0 percent by weight. In other embodiments, the amount is 0.1 to 1.0 percent or 0.15 to 0.75 percent of the final blended fluid formulation. In a concentrate, the amounts will be proportionately higher.

[0025] The boron-containing compound can include boron containing friction modifiers, such as, for example, borated fatty epoxides, borated glycerol esters, and borated alkoxylated fatty amines.

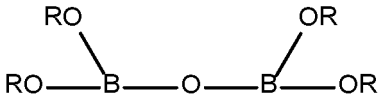
[0026] The boron containing compound can also include borated detergents. The borated detergents can include, for example, overbased borated materials, which are described in U.S. Patents 5,403,501 and 4,792,410.

[0027] The boron containing compound can also include a borate ester. The borate ester may be a compound represented by one or more of the formulae:



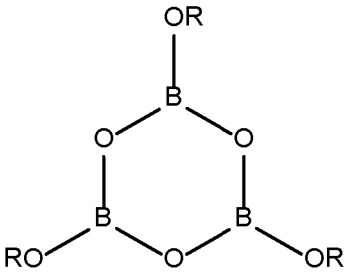
I,

or



III,

or



V,

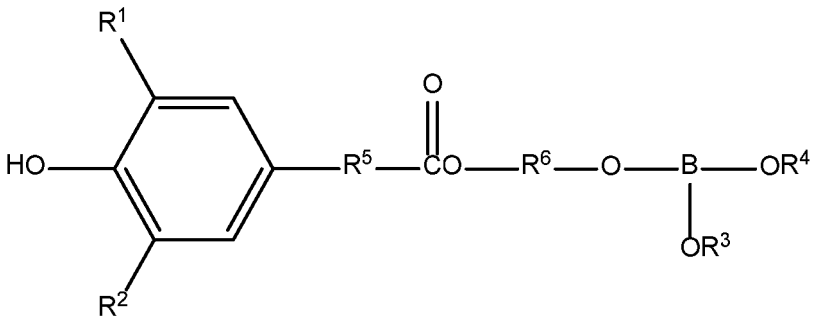
wherein each R can be, independently a hydrocarbyl group, as that term is defined herein, and any two adjacent R groups may together form a cyclic group. Mixtures of two or more of the foregoing may be used. The total number of carbon atoms in the R groups in each formula should be sufficient to render the compound soluble in the oil of lubricating viscosity. Generally, the total number of carbon atoms in the R groups is at least about 3, and in one embodiment at least about 5, and in one embodiment at least about 8. There is no limit to the total number of carbon atoms in the R groups that is required, but a practical upper limit is about 400 or about 500 carbon atoms.

[0028] In embodiments, each R can independently be a hydrocarbyl group containing 1 to 14, or from 2 to 13 or even 3 to 10 or 12 carbon atoms, provided the sum total number of carbon atoms in all R is 3 or more, preferably 4 or more and even more preferably 6 or more. In some embodiments, each R, independently, can be a C_3 to C_{22}, or C_3 to C_{18}, or C_3 to C_{12} alkyl. Examples of useful R groups include isopropyl, n-butyl, isobutyl, amyl, 4-methyl-2-pentyl, 2-ethyl-1-hexyl, isooctyl, decyl, dodecyl, 2-propylheptyl, tetradecyl, 2-pentenyl, dodecenyl, phenyl, naphthyl, alkylphenyl, and the like.

[0029] Suitable examples of the borate ester include, for example, tripropyl borate, tributyl borate, tripentyl borate, trihexyl borate, triheptyl borate, trioctyl borate, trinonyl borate and tridecyl borate. Other borate ester examples can include, for example, the compound of formula I, wherein each R is, independently, a C_3 to C_{22}, or C_3 to C_{18}, or C_3 to C_{12} alkyl, such as, for example, tri-2-ethylhexyl borate, tris(2-propylheptyl) borate and mixtures thereof. In an embodiment the borate ester can be a Cs borate ester, or a C_{10} borate ester. In one embodiment the borate ester can be tris(2-propylheptyl) borate. In some embodiments the borate ester can be tri-2-ethylhexyl borate.

[0030] In one embodiment, the borated ester can be represented by the formula $B(OC_5H_{11})_3$ or $B(OC_4H_9)_3$. In one embodiment, the borated ester can be tri-n-butyl borate.

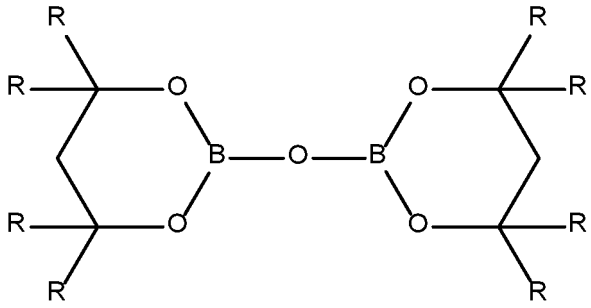
[0031] In one embodiment, the borated ester can be a phenolic compound represented by the formula



VII

wherein in formula VII: R_1, R_2, R_3 and R_4 are independently hydrocarbyl groups of 1 to about 12 carbon atoms; and R_5 and R_6 are independently alkylene groups of 1 to about 6 carbon atoms, and in one embodiment about 2 to about 4 carbon atoms, and in one embodiment about 2 or about 3 carbon atoms. In one embodiment, R_1 and R_2 independently contain 1 to about 6 carbon atoms, and in one embodiment each is a t-butyl group. In one embodiment, R_3 and R_4 are independently hydrocarbyl groups of about 2 to about 12 carbon atoms, and in one embodiment about 8 to about 10 carbon atoms. In one embodiment, R_5 and R_6 are independently --CH_2CH_2 -- or-$CH_2CH_2CH_2$ --.

[0032] In one embodiment, the borated ester can be a compound represented by the formula:



IX

wherein in formula IX, each R is independently hydrogen or a hydrocarbyl group. Each of the hydrocarbyl groups may contain from 1 to about 12 carbon atoms, and in one embodiment 1 to about 4 carbon atoms. An example is 2,2'-oxy-bis-(4,4,6-time-thyl-1,3,2-dioxaborinane).

[0033] The borate ester may be employed in the lubricant composition at about 0.2 or 0.3 to about 2.0 wt.% based on the weight of the lubricant composition, or in some cases about 0.35 to 2.0 wt.%, and in one embodiment from about 0.25 to about 1.0 wt.%, and in one embodiment about 0.25 to about 0.75 wt.%.

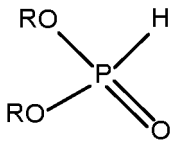
Phosphorus Containing Compound

[0034] The lubricant composition contains at least one phosphorous containing compound. The phosphorus-containing compound may be an acid, salt or ester. In one embodiment the phosphorus-containing compounds are in the form of a mixture of two or three, or two to four (typically two or three) phosphorus-containing compounds.

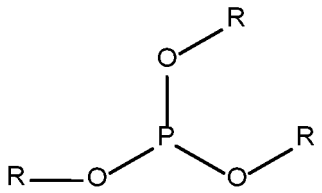
[0035] In some embodiments the phosphorus-containing compound is a phosphite. Suitable phosphites include those having at least one hydrocarbyl group with 3 or 4 or more, or 8 or more, or 12 or more, carbon atoms. The phosphite may be a mono-hydrocarbyl substituted phosphite, a di-hydrocarbyl substituted phosphite, or a tri-hydrocarbyl substituted phosphite.

[0036] In one embodiment the phosphite is sulphur-free i.e., the phosphite is not a thiophosphite.

[0037] The phosphite may be represented by the formulae:



XI



XII

wherein at least one R may be a hydrocarbyl group containing at least 3 carbon atoms and the other R groups may be hydrogen. In one embodiment, two of the R groups are hydrocarbyl groups, and the third is hydrogen. In one embodiment every R group is a hydrocarbyl group, i.e., the phosphite is a tri-hydrocarbyl substituted phosphite. The hydrocarbyl groups may be alkyl, cycloalkyl, aryl, acyclic or mixtures thereof.

[0038] The R hydrocarbyl groups may be linear or branched, typically linear, and saturated or unsaturated, typically saturated.

[0039] In one embodiment, the phosphorus-containing compound can be a C_{3-8} hydrocarbyl phosphite, or mixtures thereof, i.e., wherein each R may independently be hydrogen or a hydrocarbyl group having 3 to 8, or 4 to 6 carbon atoms, typically 4 carbon atoms. Typically, the C_{3-8} hydrocarbyl phosphite comprises dibutyl phosphite. The C_{3-8} hydrocarbyl phosphite may deliver at least 175 ppm, or at least 200 ppm of the total amount of phosphorus delivered by the phosphorus-containing compounds. The C_{3-8} hydrocarbyl phosphite may deliver at least 45 wt %, or 50 wt % to 100 wt %, or 50 wt % to 90 wt % or 60 wt % to 80 wt % of the total amount of phosphorus from the phosphorus-containing compound.

[0040] In one embodiment, the phosphorus-containing compound can be a C_{12-22} hydrocarbyl phosphite, or mixtures thereof, i.e., wherein each R may independently be hydrogen or a hydrocarbyl group having 12 to 24, or 14 to 20 carbon atoms, typically 16 to 18 carbon atoms. Typically, the C_{12-22} hydrocarbyl phosphite comprises a C_{16-18} hydrocarbyl phosphite. Examples of alkyl groups for R^3, R^4 and R^5 include octyl, 2-ethylhexyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, octadecenyl, nonadecyl, eicosyl or mixtures thereof. The C_{12-22} hydrocarbyl phosphite may be present in the lubricant composition at about 0.05 wt.% to about 1.0 wt.% of the lubricant composition, or from about 0.1 wt.% to about 0.5 wt.% of the lubricant composition.

[0041] In some embodiments, the phosphorous containing compound can include both a C_{3-8} and a C_{12} to C_{24} hydrocarbyl phosphite.

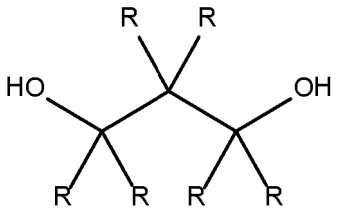
[0042] The phosphorus containing compound can be a phosphite ester composition that is the reaction product, e.g., condensation product, of a monomeric phosphorous acid or an ester thereof with at least two alkylene diols. In an embodiment, the foregoing phosphite ester does not contain zinc.

[0043] By "monomeric" phosphorous acid or ester is meant a phosphorous acid or ester, typically containing one phosphorus atom, which may be reacted with a diol in order to form an oligomeric, polymeric, or other condensed species. The monomeric phosphorous acid or ester thereof may be phosphorous acid itself (H_3PO_3), although a monomeric partial ester such as a dialkylphosphite may be used for ease of handling or other reasons. The alkyl group or groups may be relatively low molecular weight groups of 1 to 6 or 1 to 4 carbon atoms, such as methyl, ethyl, propyl, or butyl, such that the alcohol generated upon reaction with the alkylene diols may be easily removed. An exemplary phosphorous acid ester is dimethyl phosphite; others include diethyl phosphite, dipropyl phosphite, and dibutyl phosphite. Sulfur-containing analogues may also be employed (e.g., thiophosphites). Other esters include trialkyl phosphites. Mixtures of di-and trialkyl phosphites may also be useful. In these materials, the alkyl groups may be the same or different each independently typically having 1 to 6 or 1 to 4 carbon atoms as described above.

[0044] The monomeric phosphorus acid or ester will be reacted or condensed with at least two alkylene diols to form a phosphorus containing compound, which may include a polymeric (or oligomeric) phosphorus ester and optionally monomeric species. The first alkylene diol (i) will be a 1,4- or 1,5- or 1,6- alkylene diol. That is to say, there will be two hydroxy groups in a 1,4 or 1,5 or 1,6 relationship to each other, separated by a chain of 4, 5, or 6 carbon atoms, respectively. The first hydroxy group may be literally on the 1 carbon atom, that is, on the α carbon of the diol, or it may be on a higher numbered carbon atom. For example, the diol may also be a 2,5- or 2,6-, or 2,7-diol or a 3,6- or 3,7- or 3,8-diol, as will be evident to the skilled person. The alkylene diol may be branched (e.g., alkyl-substituted) or unbranched and in one embodiment is unbranched. Unbranched, that is, linear diols (α,ω-diols) include 1,4-butanediol, 1,5-pentane diol, and 1,6-hexanediol. Branched or substituted diols include 1,4-pentanediol, 2-methyl-1,5-pentanediol, 3-methyl-1,5-pentanediol, 3,3-dimethyl-1,5-pentanediol, 1,5-hexanediol, 2,5-hexanediol, and 2,5-dimethyl-2,5-hexanediol. A diol having one or more secondary hydroxy groups (such as 2,5-hexanediol) may be referred to as a branched or substituted diol, even though the carbon chain itself may be linear. The location of the hydroxy groups in the 1,4-, 1,5-, or 1,6-positions (that is, either positions relative to each other or literal positions) may be helpful to promote oligomerization with the phosphorous species rather than formation of cyclic structures (which would be sterically disfavored). In certain embodiments the first alkylene diol may be 1,6-hexanediol.

[0045] The first alkylene dihydroxy compound (diol) may, if desired, have additional hydroxy groups, that is, more than two per molecule, or there may be exactly two. In one embodiment, there are exactly two hydroxy groups per molecule. If there are more than two hydroxy groups, care should be taken to assure that there is no excessive cyclization such as might interfere with the polymerization reaction, if there are fewer than 4 atoms separating any of the hydroxy groups. Also, care should be taken to avoid excessive branching or crosslinking in the product, which could lead to undesirable gel formation. Such problems may be avoided by careful control of reaction conditions such as control of the ratio of reagents and the order of their addition, performing the reaction under suitably dilute conditions, and reacting under low acid conditions. These conditions can be determined by the person skilled in the art with only routine experimentation.

[0046] The phosphorous acid or ester is also reacted with a second alkylene diol (ii). The second alkylene diol is an alkyl-substituted 1,3-propylene diol with one or more of the alkyl substituents thereof being on one or more of the carbon atoms of the propylene unit, the total number of carbon atoms in the alkyl-substituted 1,3-propylene diol being 5 to 12 or 6 to 12 or 7 to 11 or 8 to 18 or, in certain embodiments, 9. That is, the alkyl-substituted 1,3-propylene diol may be represented by the general formula



where the various R groups may be the same or different and may be hydrogen or an alkyl group, provided that at least 1 R is an alkyl group and that the total number of carbon atoms in the R groups is 2 to 9 or 3 to 9, so that the total carbon atoms in the diol will be 5 to 12 or 6 to 12, respectively, and likewise for the other ranges of total carbons. By analogy with the above-described, 1,4-, 1,5-, or 1,6-diols, reference here to 1,3-diols means that the two hydroxy groups are in a 1,3 relationship to each other, that is, separated by a chain of 3 carbon atoms. A 1,3-diol may thus also be named as a 2,4- or 3,5-diol. If the 1,3-diol has one or more secondary hydroxy groups, such a molecule will be considered to be a substituted diol. In one embodiment the number of alkyl substituents is 2 and the total number of carbon atoms in the molecule is 9. Suitable substituents may include, for instance, methyl, ethyl, propyl, and butyl (in their various possible isomers).

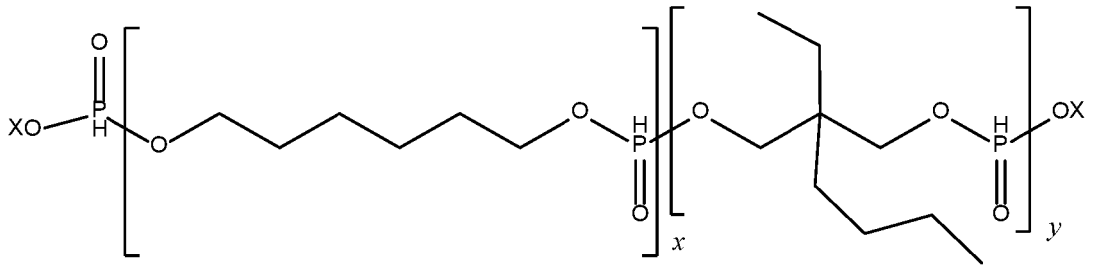
[0047] Examples of the second alkylene diol may include 2,2-dimethyl-1,3-propanediol, 2-ethyl-2-butylpropane-1,3-diol, 2-ethylhexane-1,3-diol, 2,2-dibutylpropane-1,3-diol, 2,2-diisobutylpropane-1,3-diol, 2-methyl-2-propylpropane-1,3-diol, 2-propyl-propane-1,3-diol, 2-butylpropane-1,3-diol, 2-pentylpropane-1,3-diol, 2-methyl-2-propylpropane-1,3-diol, 2,2-diethylpropane-1,3-diol, 2,2,4-trimethylpentane-1,3-diol, 2-methylpentane-2,4-diol, 2,4,-dimethyl-2,4-pentanediol, and 2,4-hexanediol. It should be noted that some of the foregoing nomenclature emphasizes the propane-1,3-diol structure of the molecules, for clarity. For instance, 2-pentylpropane-1,3-diol might also be named 2-hydroxymethylheptan-1-ol, but the latter nomenclature does not so clearly illustrate the 1,3-nature of the diol.

[0048] The relative molar amounts of the first alkylene diol (i) and the second alkylene diol (ii) may be in a ratio of 30:70 to 65:35, or alternatively 35:65 to 60:40 or 40:60 to 50:50 or 40:60 to 45:55. If the ratio is less than about 30:70, the resulting product may not fully exhibit the benefits of the disclosed technology, and if it is greater than about 65:35, its compatibility with other components in a lubricant formulation may be reduced.

[0049] The relative molar amounts of the monomeric phosphorous acid or ester thereof (a) and the total molar amounts of the alkylene diols (b) may be in a ratio of 0.9:1.1 to 1.1:0.9, or 0.95:1.05 to 1.05:0.95, or 0.98:1.02 to 1.02:0.98, or about 1:1. Reaction in approximately equimolar ratios will tend to encourage formation of oligomers or polymer formation. An exact 1:1 ratio could theoretically lead to extremely long chain formation and consequently very high molecular weight. In practice, however, this is not typically attained since competing reactions and incompleteness of reaction will provide materials of a lesser degree of polymerization, and a certain fraction of the material will be in the form of cyclic monomer.

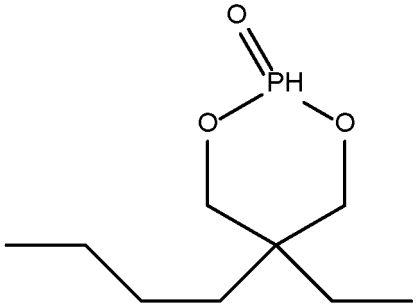
[0050] The reaction product will typically comprise a mixture of individual species, including some oligomeric or polymeric species as well as cyclic monomeric species. The cyclic monomeric species may comprise 1 phosphorus atom and one alkylene group, derived principally from the 1,3-diol (ii), as the 1,3-diol is capable of either participation in oligomerization or cyclic ester formation. The oligomeric or polymeric species may typically comprise 2 or 3 to 20 phosphorus atoms, or alternatively 5 to 10 phosphorus atoms, linked together by alkylene groups derived from the diols (i) and (ii), and may exhibit a relative preference for incorporation of the 1,4-, 1,5-, or 1,6-diols, which are less readily able to cyclize with the phosphorus to form a cyclic monomeric species.

[0051] The product may be a mixture of species that may be represented by the structures shown:



(oligomeric species)

plus



(cyclic monomer species)

where x and y represent the relative amounts of the two diols incorporated into the oligomer. The structure shown is not intended to indicate that the polymer is necessarily a block polymer, since the structures represented by the x and y brackets may be more or less randomly distributed, as influenced by or depending on the availability of the various diol reactants. Each X is independently a terminating group, which may be, for instance, an alkyl group (such as methyl), or hydrogen or a diol-derived moiety which might terminate in an OH group. In the above scheme, for illustrative purposes only, the diene (i) is selected to be 1,6-hexanediol and diene (ii) is selected to be 2-butyl-2-ethyl-1,3-propanediol. Corresponding structures and mixtures would be formed using different diols (i) and (ii).

[0052] The relative amounts of oligomeric species and cyclic monomer species in the reaction mixture will depend, to some extent, on the specific diols selected and the reaction conditions. For reaction products prepared from 1,6-hexane diol and 2-butyl-2-ethyl-1,3-propanediol, as in the structures above, the amount of oligomeric product may be approximately as shown in the table below:

mol % 1,6-diol	30	40	50	60	65
wt. % oligomer	52	58	62	70	71

and the amount of the cyclic monomer may be 100% minus the percentage of the oligomer. It is also possible that, regardless of the specific diols employed, mixtures having the above weight percentages of oligomer and cyclic monomer may be usefully prepared. In certain embodiments, 55 to 60 weight percent of the product is in oligomeric form and 45 to 40 percent is in cyclic monomer form. In some embodiments the relative amount of the cyclic monomeric species to the amount of the oligomeric species is 1:3 to 1:1 or alternatively 1:3 to 1:0.8 by weight.

[0053] The condensation reaction between the phosphorus acid or ester and the diol may be accomplished by mixing the reagents and heating until the reaction is substantially complete. Typically, the first and second alkylene diols may be mixed with the phosphorous compound at the same time or nearly the same time, that is, typically before the reaction with one of the alkylene diols is complete. A small amount of a basic material such as sodium methoxide may also be present. If a methyl ester of the phosphorous acid is used as a reagent, substantial completion of the reaction may correspond with the cessation of evolution and distillation of methanol from the reaction mixture. Suitable temperatures include those in the range of 100 to 140°C, such as 110 to 130°C or 115 to 120°C. If reaction temperatures in excess of about 140°C are employed, there is a risk that the desired product may not be formed in useful yields or with useful purity, since competing reactions may occur. Reaction times may typically be up to 12 hours, depending on temperature, applied pressure (if any), agitation, and other variables. In some instances, reaction times of 2 to 8 hours or 4 to 6 hours

may be appropriate.

[0054] Other monomers may be included within the reaction mixture if desired. The inclusion of a polycarboxylic acid, such as a dicarboxylic acid, is sometimes seen as beneficial. For example, inclusion of a relatively minor amount of tartaric acid or citric acid may provide products with useful properties. The amount of polyacid or diacid may an amount suitable to incorporate at least 1, or approximately 1, monomeric unit of poly- or dicarboxylic acid per product oligomer molecule. The amount of polyacid or diacid actually charged to the reaction mixture may be higher than this amount. Without intending to be bound by any theory, it is believed that when a minor amount of tartaric acid is present, it may be incorporated as an end unit of the polymer, possibly being condensed through an ester linkage with an OH group of an alkylene diol. Such materials may exhibit good performance in terms of antiwear protection and corrosion inhibition, as well as seals performance. Suitable polyacids (or their esters or anhydrides) include maleic acid, fumaric acid, tartaric acid, citric acid, phthalic acid, terephthalic acid, malonic acid (e.g., ester), succinic acid, malic acid, adipic acid, oxalic acid, sebacic acid, dodecanedioic acid, glutaric acid, and glutamic acid. Another type of monomer which may be included is a monocarboxylic acid which contains a reactive hydroxy group, or a reactive equivalent of such a material, such as an anhydride, ester, or lactone. Examples include glyoxylic acid, caprolactone, valerolactone, and hydroxystearic acid.

[0055] The amount of the phosphorous ester product described above used in lubricants may be an amount sufficient to provide 0.01 to 0.3 or to 0.1 weight percent phosphorus to the composition or, in other embodiments, 0.02 to 0.07 weight percent or 0.025 to 0.05 weight percent. The actual amount of the product which corresponds to these amounts of phosphorus will, of course, depend upon its phosphorus content. Suitable amounts of the ester product in the lubricant composition may be 0.01 to 1.0 weight percent, or 0.02 to 0.5 weight percent, or 0.03 to 0.30 weight percent, or even 0.05 to 0.25 weight percent.

[0056] While each of the phosphorus containing compounds described above may be present in the lubricant composition on its own, the lubricant composition may also include a mixture of two or more. In some embodiments, the phosphorous containing compound can include a C_{3-8} hydrocarbyl phosphite and a phosphite ester product. In some embodiments, the phosphorous containing compound can include each of a C_{3-8} hydrocarbyl phosphite, a C_{12} to C_{24} hydrocarbyl phosphite, and a phosphite ester product. In either event, the phosphorus containing compound should be present in an amount to deliver 100 to 450 ppm of phosphorus to the lubricant composition. In some embodiments, the at least one phosphorus containing compound can be present in an amount to deliver 125 to 425 ppm of phosphorus, or from 150 to 400 ppm phosphorus to the lubricant composition.

[0057] The ratio of the level of phosphorous from the phosphite ester to the level of boron from the borate ester should be greater than 0.7, or greater than 0.8, or greater than 0.9 or even greater than 1.0. The ratio can be, for example, from 0.7 to 5, or 0.8 to 4, or 0.9 to 3 or 1.0 to 2.

Other Additives

[0058] The lubricant composition can contain further additives aside from the borate ester and phosphorus containing compound.

[0059] In one embodiment, the lubricant composition can include an ester of a polyol and an aliphatic carboxylic acid containing 12 to 24 carbon atoms.

[0060] Polyols include diols, triols, and alcohols with higher numbers of alcoholic OH groups. Polyhydric alcohols include ethylene glycols, including di-, tri- and tetraethylene glycols; propylene glycols, including di-, tri- and tetrapropylene glycols; glycerol; butane diol; hexane diol; sorbitol; arabitol; mannitol; sucrose; fructose; glucose; cyclohexane diol; erythritol; and pentaerythritols, including di- and tripentaerythritol; preferably, diethylene glycol, triethylene glycol, glycerol, sorbitol, pentaerythritol and dipentaerythritol.

[0061] The aliphatic carboxylic acids which form the esters are those acids containing 12 to 24 carbon atoms. Such acid can be characterized by the following general formula R_1-(CO)OH, wherein R_1 is a hydrocarbyl group, which can be a straight chain hydrocarbyl group, a branched chain or cyclic-containing hydrocarbyl group, or mixtures thereof. Straight chain hydrocarbyl group containing 12 to 24 carbon atoms are preferred, for instance, 14 to 20 or 16 to 18 carbon atoms. Such acids can be used in combination with acids with more or fewer carbon atoms as well.

[0062] Generally, the acid R_1-(CO)OH is a monocarboxylic acid since polycarboxylic acids tend to form polymeric products if the reaction conditions and amounts of reactants are not carefully regulated. Mixtures of monocarboxylic acids and minor amounts of dicarboxylic acids or anhydrides, however, can be used in preparing the esters. Examples of carboxylic acids include dodecanoic acid, stearic acid, lauric acid, behenic acid, and oleic acid.

[0063] The foregoing esters are in particular the monoesters of such polyols and such carboxylic acids. A preferred ester is glycerol monooleate. It is to be understood that glycerol monooleate, as is the case with other such materials, in its commercially available grade, is a mixture which includes such materials as glycerol, oleic acid, other long chain acids, glycerol dioleate, and glycerol trioleate. The commercial material is believed to include about 60 $\pm$ 5 percent by weight of the chemical species "glycerol monooleate," along with 35 $\pm$ 5 percent glycerol dioleate, and less than about 5 percent trioleate and oleic acid. The amounts of the monoesters, described below, are calculated based on the actual,

corrected, amount of polyol monoester present in any such mixture.

[0064] The amount of the foregoing ester in the lubricant composition is typically on the order of from about 0.01 to about 1.0 wt.%, but can also be from about 0.05 to about 0.5 or 0.8 or about 0.1 to about 0.6 wt.% of the lubricant composition.

[0065] In addition to the foregoing ester, the lubricant composition can also contain an ester of an alcohol, and an aliphatic carboxylic acid containing about 4 to about 8 carbon atoms.

[0066] The alcohol includes both monohydric alcohol and polyhydric alcohol (i.e., polyol). The carbon atoms of the alcohol may be linear, branched, or mixtures thereof.

[0067] Suitable polyols are the same as mentioned above.

[0068] When branched, the alcohol may be a Guerbet alcohol, or mixtures thereof. The Guerbet alcohols may have alkyl groups including the following: 1) alkyl groups containing C_{15-16} polymethylene groups, such as 2-C_{1-15} alkyl-hexadecyl groups (e.g. 2-octylhexadecyl) and 2-alkyl-octadecyl groups (e.g. 2-ethyloctadecyl, 2-tetradecyloctadecyl and 2-hexadecyloctadecyl); 2) alkyl groups containing C_{13-14} polymethylene groups, such as 1-C_{1-15} alkyl-tetradecyl groups (e.g. 2-hexyltetradecyl, 2-decyltetradecyl and 2-undecyltridecyl) and 2-C_{1-15} alkyl-hexadecyl groups (e.g. 2-ethyl-hexadecyl and 2-dodecylhexadecyl); 3) alkyl groups containing C_{10-12} polymethylene groups, such as 2-C_{1-15} alkyl-dodecyl groups (e.g. 2-octyldodecyl) and 2-C_{1-15} alkyl-dodecyl groups (2-hexyldodecyl and 2-octyldodecyl), 2-C_{1-15} alkyl-tetradecyl groups (e.g. 2-hexyltetradecyl and 2-decyltetradecyl); 4) alkyl groups containing C_{6-9} polymethylene groups, such as 2-C_{1-15} alkyl-decyl groups (e.g. 2-octyldecyl) and 2,4-di-C_{1-15} alkyl-decyl groups (e.g. 2-ethyl-4-butyl-decyl group); 5) alkyl groups containing C_{1-5} polymethylene groups, such as 2-(3-methylhexyl)-7-methyl-decyl and 2-(1,4,4-trimethylbutyl)-5,7,7-trimethyl-octyl groups; and 6) and mixtures of two or more branched alkyl groups, such as alkyl residues of oxoalcohols corresponding to propylene oligomers (from hexamer to undecamer), ethylene/propylene (molar ratio 16:1-1:11) oligomers, iso-butene oligomers (from pentamer to octamer), C_{5-17} α-olefin oligomers (from dimer to hexamer).

[0069] Examples of a suitable branched monohydric alcohol include 2-ethylhexanol, 2-butyloctanol, 2-hexyldecanol, 2-octyldodecanol, 2-decyltetra-decanol, isotridecanol, iso-octanol, oleyl alcohol, Guerbet alcohols, or mixtures thereof. Examples of a monohydric linear alcohol include methanol, ethanol, propanol, butanol, pentanol, hexanol, heptanol, octanol, nonanol, decanol, undecanol, dodecanol, tridecanol, tetradecanol, pentadecanol, hexadecanol, heptadecanol, octadecanol, non-adecanol, eicosanol, or mixtures thereof. In one embodiment the monohydric alcohol contains 6 to 30, or 8 to 20, or 8 to 15 carbon atoms (typically 8 to 15 carbon atoms).

[0070] The aliphatic carboxylic acids which form the esters are those acids containing 4 to 8 carbon atoms. While aliphatic, the aliphatic carboxylic acids can contain ethylenic unsaturation along the C_4 to C_8 alkyl group backbone. In addition, such acids can be mono-carboxylic or di-carboxylic acids or anhydrides, or mixtures thereof. Examples of carboxylic acids include, for example, succinic acid, maleic acid, fumaric acid, glutaconic acid, glutaric acid, adipic acid, citraconic acid, mesaconic acid, pimelic acid, suberic acid, butyric acid, valeric acid, caproic acid, enanthic acid, caprylic acid and the like.

[0071] A particularly preferred ester can be an adipate ester, such as, for example, a C_{8-13} or C_{8-12} adipate ester, such as diisoctyl adipate or di-tridecyl adipate. Other esters can include, for example, pentaerythritol esters, neo-pentyl esters and trimethylol esters.

[0072] The amount of the foregoing ester in the lubricant composition is typically on the order of from about 0.1 to about 3.0 wt.%, but can also be from about 0.2 to about 2.5 or about 0.3 to about 2.0 wt.% of the lubricant composition.

[0073] The carboxylic esters are prepared by the very well-known reaction of at least one carboxylic acid (or reactive equivalent thereof, such as ester, halide, or anhydride) with at least one of the above-described hydroxy compounds.

[0074] Another component of the lubricant composition can be a metal deactivator. Examples of such materials include 2,5-dimercapto-1,3,4-thiadiazole and/or derivatives thereof. Such materials are described in European Patent Publication 0761805, incorporated herein by reference.

[0075] The metal deactivators that are useful herein reduce the corrosion of metals, such as copper. Metal deactivators are also referred to as metal passivators. These metal deactivators are typically nitrogen and/or sulfur containing heterocyclic compounds, such as dimercaptothiadiazoles, triazoles, aminomercaptothiadiazoles, imidazoles, thiazoles, tetrazoles, hydroxyquinolines, oxazolines, imidazolines, thiophenes, indoles, indazoles, quinolines, benzoxazines, dithiols, oxazoles, oxatriazoles, pyridines, piperazines, triazines, and derivatives of any one or more thereof. The metal deactivator preferably comprises at least one triazole, which may be substituted or unsubstituted. Examples of suitable compounds are benzotriazole, alkyl-substituted benzotriazole (e.g., tolyltriazole, ethylbenzotriazole, hexylbenzotriazole, octylbenzotriazole, etc.), aryl-substituted benzotriazole (e.g., phenol benzotriazoles, etc.), and alkylaryl- or arylalkyl-substituted benzotriazole and substituted benzotriazoles where the substituent may be hydroxy, alkoxy, halo (especially chloro), nitro, carboxy and carboxyalkoxy. Preferably, the triazole is a benzotriazole or an alkylbenzotriazole in which the alkyl group contains 1 to about 20 carbon atoms, preferably 1 to about 8 carbon atoms. Benzotriazole and tolyltriazole are useful.

[0076] In one embodiment, the metal deactivator is the reaction product of a dispersant with a dimercaptothiadiazole. The dispersants may be generally characterized as the reaction products of carboxylic acids with amines and/or alcohols.

These reaction products are commonly used in the lubricant arts as dispersants and are sometimes referred to generically as dispersants despite the fact that they may have other uses in addition to or instead of that as dispersants. The carboxylic dispersants include succinimide dispersants, ester type dispersants and the like. Succinimide dispersants are generally the reaction of a polyamine with an alkenyl succinic anhydride or acid. Ester type dispersants are the reaction product of an alkenyl succinic anhydride or acid with a polyol compound. The reaction product may then be further treated with an amine such as a polyamine. Examples of useful dispersants are disclosed in U.S. Pat. Nos. 3,219,666 and 4,234,435, incorporated herein by reference. Useful dispersants also include the ashless dispersants discussed below. Generally, the reaction occurs between the dispersant and the dimercaptothiadiazole by mixing the two and heating to a temperature above about 100 °C. U.S. Pat. Nos. 4,140,643 and 4,136,043 describe compounds made by the reaction of such dispersants with a dimercaptothiadiazole. These patents are incorporated herein by reference for their disclosure of dispersants, dimercaptothiadiazole, the method for reacting the two and the products obtained from such reaction.

[0077] In one embodiment, the metal deactivator is the reaction product of a phenol with an aldehyde and a dimercaptothiadiazole. The phenol is preferably an alkyl phenol wherein the alkyl group contains at least about 6, preferably from 6 to about 24, more preferably about 6, or about 7, to about 12 carbon atoms. The aldehyde is preferably an aldehyde containing from 1 to about 7 carbon atoms or an aldehyde synthon, such as formaldehyde. Preferably, the aldehyde is formaldehyde or paraformaldehyde. The aldehyde, phenol and dimercaptothiadiazole are typically reacted by mixing them at a temperature up to about 150 °C, preferably about 50 °C to about 130 °C, in molar ratios of about 0.5 to about 2 moles of phenol and about 0.5 to about 2 moles of aldehyde per mole of dimercaptothiadiazole. Preferably, the three reagents are reacted in equal molar amounts.

[0078] In one embodiment, the metal deactivator is a bis(hydrocarbyldithio)thiadiazole. Preferably each hydrocarbyl group is independently an alkyl, aryl or aralkyl group, having from 6 to about 24 carbon atoms. Each hydrocarbyl can be independently t-octyl, nonyl, decyl, dodecyl or ethylhexyl. The metal deactivator can be bis-2,5-tert-octyl-dithio-1,3,4-thiadiazole or a mixture thereof with 2-tert-octylthio-5-mercapto-1,3,4-thiadiazole. These materials are available commercially under the trade name of Amoco 150, which is available from Amoco Chemical Company. These dithiothiadiazole compounds are disclosed as Component (d) in PCT Publication WO 88/03551.

[0079] In the preferred embodiments the metal deactivator is a dimercaptothiadiazole derivative. The following D-1 and D-2 are specific examples.

Example D-1

[0080] 2,5-dimercapto-1,3,4-thiadiazole oxidatively coupled with t-nonyl mercaptan; 100% chemical, 36% S, 64% N.

Example D-2

[0081] Heptylphenol coupled with 2,5-dimercapto-1,3,4-thiadiazole using formaldehyde (the thiadiazole is generated in situ); 20% oil, 17.75% S, 5.5% N.

[0082] When used, the amount of metal deactivator in the lubricant composition is generally in the range of about 0.01 to about 0.5 wt.% by weight of the lubricant composition. In some embodiments, the amount of the metal deactivator is in the range of about 0.02 to about 0.42 wt.% or about 0.03 to about 0.33 wt,% or about 0.04 to about 0.24 wt.% by weight of the lubricant composition.

[0083] The lubricant composition can also contain a poly(meth)acrylate polymer viscosity modifier. As used herein ranges below for the viscosity modifier are measured by GPC using polystyrene standards with a weight average molecular weight ranging from 350 to 2,000,000.

[0084] The lubricant composition in one embodiment includes a linear poly(meth)acrylate polymer with a weight average molecular weight of 5,000 to 25,000, or 8000 to 20,000.

[0085] The linear poly(meth)acrylate polymer may be present in the lubricant composition at about 0.1 wt % to about 5 wt %, or 0.1 wt % to 4 wt %, or 0.2 wt % to 3 wt %, or 0.5 wt % to 3 wt %, 0.5 wt % to 4 wt % of the lubricating composition.

[0086] The poly(meth)acrylate polymer may be derived from a monomer composition comprising:(a) 50 wt % to 95 wt %, or 60 wt % to 80 wt % of an alkyl (meth)acrylate, wherein the alkyl group of the (meth)acrylate has 10 to 15 carbon atoms; (b) 1 wt % to 40 wt %, or 4 wt % to 35 wt % of an alkyl (meth)acrylate, wherein the alkyl group of the (meth)acrylate has 1 to 9 carbon atoms; (c) 1 wt % to 10 wt %, or 1 wt % to 8 wt % of a monomer having dispersant functionality, (d) 0 wt % to 4 wt %, or 0 wt % to 2 wt %, or 0 wt % of a vinyl aromatic monomer (typically styrene); and (e) 0 wt % to 9 wt %, or 0 wt % to 6 wt % of an alkyl (meth)acrylate, wherein the alkyl group of the (meth)acrylate has 16 to 18 carbon atoms. In one embodiment the linear polymer may contain 0 wt % to 20 wt % of 16 to 18 alkyl (meth)acrylate.

[0087] In one embodiment the linear polymer includes a poly(meth)acrylate (typically a polymethacrylate) with units derived from a mixture of alkyl (meth)acrylate ester monomers containing, (a) 8 to 24, or 10 to 18, or 12 to 15 carbon atoms in the alcohol-derived portion of the ester group and (b) 6 to 11, or 8 to 11, or 8 carbon atoms in the alcohol-

derived portion of the ester group, and which have 2-(C_{1-4} alkyl)-substituents, and optionally, at least one monomer selected from the group consisting of (meth)acrylic acid esters containing 1 to 7 carbon atoms in the alcohol-derived portion of the ester group and which are different from (meth)acrylic acid esters (a) and (b), vinyl aromatic compounds (or vinyl aromatic monomers); and nitrogen-containing vinyl monomer; provided that no more than 60% by weight, or no more than 50% by weight, or no more than 35% by weight of the esters contain no more than 10 carbon atoms in the alcohol-derived portion of the ester group. The linear polymer of this type is described in more detail in US 6,124,249, or EP 0 937 769 A1 paragraphs [0019] and [0031] to [0067]. (The "alcohol-derived portion" refers to the "-OR" portion of an ester, when written as R'C(=O)-OR, whether or not it is actually prepared by reaction with an alcohol.) Optionally, the linear polymer may further contain a third monomer. The third monomer may be styrene, or mixtures thereof. The third monomer may be present in an amount 0% to 25% of the polymer composition, or from 1% to 15% of the composition, 2% to 10% of the composition, or even from 1% to 3% of the composition.

[0088] Typically, the mole ratio of esters (a) to esters (b) in the copolymer ranges from 95:5 to 35:65, or 90:10 to 60:40, or 80:20 to 50:50.

[0089] The esters are usually aliphatic esters, typically alkyl esters. In one embodiment the ester of (a) may be a C_{12-15} alkyl (meth)acrylate and the ester of (b) may be 2-ethylhexyl (meth)acrylate.

[0090] In one embodiment, the ester groups in ester (a) contain branched alkyl groups. The ester groups may contain 2 to 65%, or 5 to 60% of the ester groups having branched alkyl groups. The branched alkyl groups may be β-branched and may contain 8 to 60, or 8 to 30, or 8 to 16 carbon atoms. For examples branched alkyl groups may be derived from 2-ethylhexanol, 2-butyloctanol, 2-hexyldecanol, 2-octyldodecanol, 2-decyltetradecanol, or mixtures thereof, or commercially available alcohols such as Isofol® branched Guerbet alcohols available from Sasol.

[0091] The C_{1-4} alkyl substituents may be methyl, ethyl, and any isomers of propyl and butyl.

[0092] The weight average molecular weight of the linear poly(meth)acrylate may be 45,000 or less, or 35,000 or less, or 25,000 or less, or 8000 to 25,000, or, 10,000 to 35,000, or 12,000 to 20,000.

[0093] The linear polymer may be called a viscosity modifier, or a dispersant viscosity modifier as it may exhibit dispersant functionality. Reference to a "dispersant viscosity modifier" herein is exclusive of dispersants, which are a separate class of compounds. The linear polymer may be used as a sole viscosity modifier (or dispersant viscosity modifier) present at 0.5 wt % to 4 wt % of a linear (meth)acrylic polymer viscosity modifier having dispersant functionality, wherein the linear polymer has a weight average molecular weight of 5,000 to 25,000, or 10,000 to 20,000, and wherein oil the of lubricating viscosity has a kinematic viscosity at 100°C of 2.8 to 3.1 cSt (mm^2/s) and a viscosity index of 104 to 130.

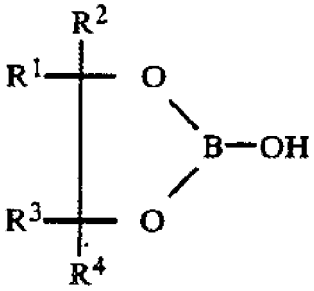
[0094] The lubricant composition in one embodiment may contain only two linear polymer viscosity modifiers having dispersant functionality, wherein the linear polymer has a weight average molecular weight of 5,000 to 25,000, or 10,000 to 20,000,

[0095] In one embodiment the lubricating composition may comprise 0.1 wt% to 4 wt % (or 0.2 wt % to 3 wt %) of a linear (meth)acrylic polymer viscosity modifier having dispersant functionality, wherein the linear polymer has a weight average molecular weight of greater than 25,000 to 400,000 (or to 350,000) or 30,000 to 150,000. The linear (meth)acrylic polymer a weight average molecular weight of greater than 25,000 to 400,000 (or to 350,000) may be considered chemically similar to the linear (meth)acrylic polymer a weight average molecular weight of 5,000 to 25,000 except the weight average molecular weight is different.

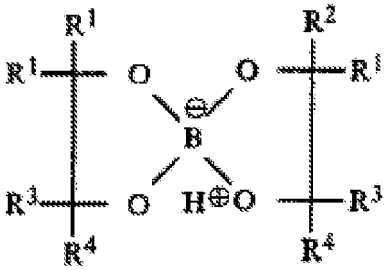
[0096] The lubricating composition may comprise a linear polymer viscosity modifier having dispersant functionality comprises: 0.1 wt % to 4 wt % (or 0.2 wt % to 3 wt %) of a linear (meth)acrylic polymer viscosity modifier having dispersant functionality, wherein the linear polymer has a weight average molecular weight of 10,000 to 20,000; and 0.1 wt % to 4 wt % (or 0.2 wt % to 3 wt %) of a linear (meth)acrylic polymer viscosity modifier having dispersant functionality, wherein the linear polymer has a weight average molecular weight of greater than 20,000 to 250,000 (or 30,000 to 150,000).

[0097] As described hereinafter the molecular weight of the viscosity modifier has been determined using known methods, such as GPC analysis using polystyrene standards. Methods for determining molecular weights of polymers are well known. The methods are described for instance: (i) P.J. Flory, "Principles of star polymer Chemistry", Cornell University Press 91953), Chapter VII, pp 266-315; or (ii) "Macromolecules, an Introduction to star polymer Science", F. A. Bovey and F. H. Winslow, Editors, Academic Press (1979), pp 296-312.

[0098] Another component of the present invention is a borated epoxide containing 12-24 carbon atoms. This material can alternatively described as a borate ester of a vicinal diol containing 12 to 24 carbon atoms. Such a material may be represented by the structures



or



wherein each of R^1, R^2, R^3, and R^4 are independently hydrogen or an aliphatic radical, or any two thereof together with the carbon atom or atoms to which they are attached form a cyclic radical. Preferably at least one of the R groups is an alkyl group containing at least 8 or at least 10 carbon atoms. In one embodiment one of the R groups is such an alkyl group and the remaining R groups are hydrogen. Borated epoxides are described in detail in U.S. Pat. No. 4,584,115. Borated epoxides are generally prepared by reacting an epoxide with a boron source such as boric acid or boron trioxide. Borated epoxides are not themselves epoxides, but are the ring-opened boron-containing reaction products of epoxides. Suitable epoxides include commercial mixtures of C_{14-16} or C_{14-18} or C_{16-18} epoxides, which can be purchased from Elf-Atochem or Union Carbide and which can be prepared from the corresponding olefins by known methods. Purified epoxy compounds such as 1,2-epoxyhexadecane can be purchased from Aldrich Chemicals. The borated compounds are prepared by blending the boron compound and the epoxide and heating them at a suitable temperature, typically 80° to 250°C, until the desired reaction has occurred. An inert liquid, such as toluene, xylene, or dimethylformamide can be used as a reaction medium. Water is formed and is typically distilled off during the reaction. Alkaline reagents can be used to catalyze the reaction. A preferred borated epoxide is the borated epoxide of a predominantly 16 carbon olefin. The amount of the borate epoxide can be 0.01 or 0.05 to 0.5 or 1.0 parts by weight of the composition, or alternatively 0.1 to 0.9 percent.

[0099] Other optional materials may include a mixture of at least two antioxidants, e.g., aromatic amine antioxidants, hindered phenolic antioxidants including ester-containing hindered phenolic antioxidants, and sulfurized olefin antioxidants. These antioxidants may optionally be present in amounts of 0.01 to 5, or 0.15 to 4.5 or 0.2 to 4, or 0.2 to 2 percent by weight.

[0100] In one embodiment the lubricating composition of the invention includes an aryl amine antioxidant. The aryl amine antioxidant may be a phenyl-α-naphthylamine (PANA) or a hydrocarbyl substituted diphenylamine, or mixtures thereof. The hydrocarbyl substituted diphenylamine may include mono- or di- C_4 to C_{16}-, or C_6 to C_{12}-, or C_9- alkyl diphenylamine. For example, the hydrocarbyl substituted diphenylamine may be octyl diphenylamine, or di-octyl diphenylamine, dinonyl diphenylamine, typically dinonyl diphenylamine.

[0101] When present the aryl amine antioxidant may be present at 0.2 wt % to 1.2 wt %, or 0.3 wt % to 1.0 wt %, or 0.4 wt % to 0.9 wt % or 0.5 wt % to 0.8 wt %, of the lubricating composition.

[0102] The hindered phenol antioxidant often contains a secondary butyl and/or a tertiary butyl group as a sterically hindering group. The phenol group is often further substituted with a hydrocarbyl group and/or a bridging group linking to a second aromatic group. Examples of suitable hindered phenol antioxidants include 2,6-di-tert-butylphenol, 4-methyl-2,6-di-tert-butylphenol, 4-ethyl-2,6-di-tert-butylphenol, 4-propyl-2,6-di-tert-butylphenol or 4-butyl-2,6-di-tert-butylphenol, or 4-dodecyl-2,6-di-tert-butylphenol. In one embodiment the hindered phenol antioxidant may be an ester and may include, e.g., Irganox™ L-135 from Ciba, or butyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propanoate.

[0103] If present, the hindered phenol antioxidant may be present at 0.1 wt % to 1 wt %, or 0.2 wt % to 0.9 wt % or 0.1 wt % to 0.4 wt %, or 0.4 wt % to 1.0 wt %, of the lubricating composition.

[0104] Antioxidants also include sulfurized olefins such as mono-, or disulfides or mixtures thereof. These materials generally have sulfide linkages having 1 to 10 sulfur atoms, for instance, 1 to 4, or 1 or 2. Materials which can be sulfurized to employ as sulfurized antioxidants in the lubricant composition can include oils, fatty acids and esters, olefins and polyolefins made thereof, terpenes, or Diels-Alder adducts. Details of methods of preparing some such sulfurized materials can be found in U.S. Pat. Nos. 3,471,404 and 4,191,659.

[0105] The lubricating composition may also include a calcium-containing detergent. While the calcium-containing detergent is preferably not present, it can be included in an amount to deliver up to 300 ppm of calcium to the composition, or from 30 ppm to 300 ppm, or 30 ppm to 275 ppm of calcium, or from 60 ppm to 250 ppm, or even from 60 ppm to 225 ppm of calcium.

[0106] In some embodiments, the calcium-containing detergent may be present at 900 ppm or less, or from 1 to 900 ppm, or even from 5 to 800 ppm or 10 to 700 ppm, or even from 15 to 600 or 500 ppm.

[0107] The calcium-containing detergent may be an overbased detergent, a non-overbased detergent, or mixtures thereof. Typically, the detergent is overbased.

[0108] The preparation of the calcium-containing detergent is known in the art. Patents describing the preparation of overbased calcium-containing detergents include U.S. patents 2,501,731; 2,616,905; 2,616,911; 2,616,925; 2,777,874; 3,256,186; 3,384,585; 3,365,396; 3,320,162; 3,318,809; 3,488,284; and 3,629,109.

[0109] The calcium-containing detergent may be a non-overbased detergent (may also be referred to as a neutral detergent). The TBN of a non-overbased may be 20 to less than 200, or 30 to 100, or 35 to 50 mg KOH/g. The TBN of a non-overbased calcium-containing detergent may also be 20 to 175, or 30 to 100 mg KOH/g. When a non-overbased calcium-containing detergent is prepared from a strong acid such as a hydrocarbyl-substituted sulphonic acid, the TBN may be lower (for example 0 to 50 mg KOH/g, or 10 to 20 mg KOH/g).

[0110] As used herein the TBN values quoted and associated range of TBN is on "an as is basis," i.e., containing conventional amounts of diluent oil. Conventional amounts of diluent oil typically range from 30 wt % to 60 wt % (often 40 wt % to 55 wt %) of the detergent component.

[0111] The calcium-containing detergent may be an overbased detergent, having, for example, a TBN of greater than 200 mg KOH/g (typically 250 to 600, or 300 to 500 mg KOH/g).

[0112] The overbased calcium-containing detergent may be formed by the reaction of a basic calcium compound and an acidic detergent substrate. The acidic detergent substrate may include an alkyl aromatic sulphonic acid (such as, alkyl naphthalene sulphonic acid, alkyl toluene sulphonic acid or alkyl benzene sulphonic acid), an alkyl salicylic acid, or mixtures thereof.

[0113] The basic calcium compound is used to supply basicity to the detergent. The basic calcium compound is a compound of a hydroxide or oxide of the calcium.

[0114] The oxides and/or hydroxides may be used alone or in combination. The oxides or hydroxides may be hydrated or dehydrated, although hydrated is typical. In one embodiment the basic calcium compound may be calcium hydroxide, which may be used alone or mixtures thereof with other metal basic compounds. Calcium hydroxide is often referred to as lime. In one embodiment the calcium basic compound may be calcium oxide which may be used alone or mixtures thereof with other metal basic compounds.

[0115] In one embodiment the calcium-containing detergent may be a sulphonate, or mixtures thereof. The sulphonate may be prepared from a mono- or di- hydrocarbyl-substituted benzene (or naphthalene, indenyl, indanyl, or bicyclopentadienyl) sulphonic acid, wherein the hydrocarbyl group may contain 6 to 40, or 8 to 35 or 9 to 30 carbon atoms.

[0116] The hydrocarbyl group may be derived from polypropylene or a linear or branched alkyl group containing at least 10 carbon atoms. Examples of a suitable alkyl group include branched and/or linear decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, octadecenyl, nonodecyl, eicosyl, un-eicosyl, do-eicosyl, tri-eicosyl, tetra-eicosyl, penta-eicosyl, hexa-eicosyl or mixtures thereof.

[0117] In one embodiment the hydrocarbyl-substituted sulphonic acid may include polypropene benzenesulphonic acid and/or C_{16}-C_{24} alkyl benzenesulphonic acid, or mixtures thereof.

[0118] In one embodiment a calcium sulphonate detergent may be a predominantly linear alkylbenzene sulphonate detergent having a metal ratio of at least 8 as is described in paragraphs [0026] to [0037] of US Patent Application 2005065045 (and granted as US 7,407,919). In some embodiments the linear alkyl group may be attached to the benzene ring anywhere along the linear chain of the alkyl group, but often in the 2, 3 or 4 position of the linear chain, and in some instances predominantly in the 2 position.

[0119] When neutral or slightly basic, a calcium sulphonate detergent may have TBN of less than 100, or less than 75, typically 20 to 50 mg KOH/g, or 0 to 20 mg KOH/g.

[0120] When overbased, a calcium sulphonate detergent may have a TBN greater than 200, or 300 to 550, or 350 to 450 mg KOH/g.

[0121] Phenate detergents are typically derived from p-hydrocarbyl phenols or, generally, alkylphenols. Alkylphenols of this type may be coupled with sulfur and overbased, coupled with aldehyde and overbased, or carboxylated to form salicylate detergents. Suitable alkylsalicylates include those alkylated with oligomers of propylene, oligomers of butene, especially tetramers and pentamers of n-butenes, as well as those alkylated with alpha-olefins, isomerized alpha-olefins, and polyolefins like polyisobutylene. In one embodiment, the lubricating composition comprises less than 0.2 wt %, or less than 0.1 wt %, or even less than 0.05 wt % of a salicylate detergent derived from PDDP. In one embodiment, the lubricant composition comprises a salicylate detergent that is not derived from PDDP. In one embodiment, the lubricating composition comprises a salicylate detergent prepared from PDDP, such detergent contains less than 1.0 weight percent unreacted PDDP, or less than 0.5 weight percent unreacted PDDP, or is substantially free of PDDP.

[0122] The detergent may be borated or non-borated.

[0123] Chemical structures for sulphonates, and salicylate detergents are known to a person skilled in the art. The standard textbook entitled "Chemistry and Technology of Lubricants", Third Edition, Edited by R. M. Mortier and S. T. Orszulik, Copyright 2010, pages 220 to 223 under the sub-heading 7.2.6 provide general disclosures of said detergents and their structures.

[0124] In one embodiment the calcium-containing detergent may be an overbased calcium sulphonate, an overbased calcium salicylate, or mixtures thereof. Typically, the detergent may be an overbased calcium sulphonate.

[0125] In one embodiment the calcium-containing detergent may be in a mixture with a zinc-, barium-, sodium-, or magnesium- containing detergent. The zinc-, barium-, sodium-, or magnesium- containing detergent is also well known in the art and described in the same references describing a calcium-containing detergent. The TBN and metal ratios may however, differ slightly. The zinc-, barium-, sodium-, or magnesium- containing detergent may be a phenate, a sulphur-containing phenate, sulphonate, salixarate or salicylate. Typically, a zinc-, barium-, sodium-, or magnesium-containing detergent may be a magnesium phenate, a magnesium sulphur-containing phenate, or a magnesium sulphonate.

[0126] A more detailed description of the expressions "metal ratio", TBN and "soap content" are known to a person skilled in the art and explained in standard textbooks, such as, for example, "Chemistry and Technology of Lubricants", Third Edition, Edited by R. M. Mortier and S. T. Orszulik, Copyright 2010, pages 219 to 220 under the sub-heading 7.2.5. Detergent Classification.

[0127] Another material frequently used in transmissions is a dispersant. Dispersants present in the lubricant composition of the invention include, "succinimide dispersants," a species of carboxylic dispersants prepared by the reaction of a hydrocarbyl-substituted succinic anhydride or reactive equivalent thereof with an amine such as a poly(ethyleneamine); "amine dispersants," which are reaction products of relatively high molecular weight aliphatic or alicyclic halides and amines, such as polyalkylene polyamines; "Mannich dispersants," i.e., the reaction products of alkyl phenols in which the alkyl group contains at least 30 carbon atoms with aldehydes (especially formaldehyde) and amines (especially polyalkylene polyamines); and "ester dispersants," similar to the above-described succinimide dispersants except that they may be seen as having been prepared by reaction of a hydrocarbyl acylating agent and a polyhydric aliphatic alcohol such as glycerol, pentaerythritol, or sorbitol, as described in US Patent 3,381,022. Post-treated dispersants may also be used. Post-treated dispersants are generally obtained by reacting a carboxylic (e.g., succinimide), amine or Mannich dispersant with reagents such as urea, thiourea, carbon disulfide, aldehydes, ketones, carboxylic acids, hydrocarbon-substituted succinic anhydrides, nitriles, epoxides, boron compounds such as boric acid (to give "borated dispersants" as noted above), phosphorus compounds such as phosphorus acids or anhydrides, 2,5-dimercaptothiadiazole (DMTD), or an aromatic diacid having acid groups in 1,3 or 1,4 positions on a benzene ring (such as terepthahlic acid). Mixtures of dispersants can also be used. The dispersant can have a nitrogen content of greater than or equal to about 11,000 ppm by weight of the dispersant, or greater than or equal to about 11,500ppm or greater than or equal to about 12,000 ppm.

[0128] The total amount of dispersant or dispersants, whether post-treated or not (e.g., borated or non-borated, but preferably borated) or combinations thereof, in the compositions, may be, for instance, 0.01 to 1.8 percent by weight, or, for example, 0.025 to 1.5 percent or 0.05 to 1.25 weight percent of the final blended fluid formulation, although in a concentrate, the amounts will be proportionately higher. To the extent the dispersant is borated, the dispersant may provide less then 100 ppm boron, or less than 90 ppm boron, or even less than 80 ppm boron to the composition, and in some instances less than 70 ppm boron to the composition.

[0129] The lubricant composition preferably exhibits an electrical conductivity of up to 7.0×10^{-10} S/cm as measured by ASTM D2624, or from 6.5×10^{-10} S/cm, or 6.0×10^{-10} S/cm or 5.5×10^{-10} S/cm or 5.0×10^{-10} S/cm conductivity at 100°C and 500 V. It is highly preferably that the lubricant composition has no conductivity, but practically speaking conductivities on the order of 4.0×10^{-10} or 4.5×10^{-10} at 100°C may be achievable.

[0130] In an embodiment, the lubricant composition is substantially free of friction modifiers. In some embodiments, the lubricant composition is completely free of friction modifiers.

[0131] The lubricant composition will be suitable for lubricating a transmission in a vehicle with an electric motor, which may be a full electric vehicle or a hybrid-electric vehicle having both an electric motor and an engine powered by hydrocarbon or other fuels. The lubricant composition for such use in transmissions has a kinematic viscosity at 40°C of from 8 cSt to 18 cSt, or for example, from 8 cSt to 16 cSt, or even 8 cSt to 15 cSt, or from 9 cSt to 15 or 16 cSt, or, for example, from 8 cSt to 12.5 or 13 cSt, or even from 9 cSt to 12.5 or 13 cSt, or from 10 cSt to 12 cSt. One aspect is therefore a method of lubricating a transmission, in a vehicle with an electric motor, comprising supplying to the transmission a lubricant composition as disclosed herein, and operating the transmission.

[0132] The transmissions in which the lubricant composition may be suitable include automatic transmissions and dual clutch transmissions. The transmission may or may not include a shifting clutch, and, where the transmission includes a shifting clutch, the clutch may be a dry clutch or a wet clutch. In one embodiment, the lubricant may be used on a transmission that does not contain a shifting clutch. In another embodiment, the lubricant composition may be employed in a transmission having a wet clutch. In a further embodiment, the lubricant composition may be employed on a transmission having a dry clutch.

[0133] As used herein, the term "condensation product" is intended to encompass esters, amides, imides and other such materials that may be prepared by a condensation reaction of an acid or a reactive equivalent of an acid (e.g., an acid halide, anhydride, or ester) with an alcohol or amine, irrespective of whether a condensation reaction is actually performed to lead directly to the product. Thus, for example, a particular ester may be prepared by a transesterification reaction rather than directly by a condensation reaction. The resulting product is still considered a condensation product.

[0134] The amount of each chemical component described is presented exclusive of any solvent or diluent oil, which

may be customarily present in the commercial material, that is, on an active chemical basis, unless otherwise indicated. However, unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial grade material which may contain the isomers, by-products, derivatives, and other such materials which are normally understood to be present in the commercial grade.

[0135] 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 the molecule and having predominantly hydrocarbon character. Examples of hydrocarbyl groups include:

[0136] 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 a ring);

[0137] substituted hydrocarbon substituents, that is, substituents containing non-hydrocarbon groups which, in the context of this invention, do not alter the predominantly hydrocarbon nature of the substituent (e.g., halo (especially chloro and fluoro), hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulfoxy);

[0138] hetero substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this invention, contain other than carbon in a ring or chain otherwise composed of carbon atoms and encompass substituents as pyridyl, furyl, thienyl and imidazolyl. Heteroatoms include sulfur, oxygen, and nitrogen. In general, no more than two, or no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group; alternatively, there may be no non-hydrocarbon substituents in the hydrocarbyl group.

[0139] It is known that some of the materials described above may interact in the final formulation, so that the components of the final formulation may be different from those that are initially added. For instance, metal ions (of, e.g., a detergent) can migrate to other acidic or anionic sites of other molecules. The products formed thereby, including the products formed upon employing the composition of the present invention in its intended use, may not be susceptible of easy description.

[0140] As used herein, the term "about" means that a value of a given quantity is within ±20% of the stated value. In other embodiments, the value is within ±15% of the stated value. In other embodiments, the value is within ±10% of the stated value. In other embodiments, the value is within ±5% of the stated value. In other embodiments, the value is within ±2.5% of the stated value. In other embodiments, the value is within ±1% of the stated value.

[0141] Additionally, as used herein, the term "substantially" means that a value of a given quantity is within ±10% of the stated value. In other embodiments, the value is within ±5% of the stated value. In other embodiments, the value is within ±2.5% of the stated value. In other embodiments, the value is within ±1% of the stated value.

[0142] The invention herein is useful for lubricating an automatic transmission for a hybrid electric vehicle, which may be better understood with reference to the following examples.

EXAMPLES

[0143] A number of formulations were prepared and tested for pitting.

[0144] Sample formulations were blended according to the table below.

	1	2	3	4	5	6	7	8	9
Dispersant (active)	0.61	0.32	0.33	0.53	0.38	0.38	0.61	0.53	0.29
ppm B from disp	17	8	38	16	58	58	19	16	0
Borate ester	0.42	0.42	0.42	0.4	0.42	0.42	0.42	0.42	0.45
ppm B from Borate ester	113.4	113.4	113.4	108	113.4	113.4	113.4	113.4	121.5
Borate epoxide	0.14	0.11	0.11	0.14	0.15	0.15	0.14	0.14	0.11
ppm B from Borate epox	29.4	23.1	23.1	29.4	31.5	31.5	29.4	29.4	23.1
dibutyl phosphite	0.11	0.04	0.04	0.09	0.06	0.1	0.11	0.09	0.1
C16-C18 alkenyl phosphite	0.12	0.18	0.18	0.12	0.14	0.12	0.12	0.12	0.2
phosphite ester reaction product	0.08	0.14	0.14	0.11	0.12	0.1	0.08	0.11	0.1
ppm P from phos ester	120	210	210	165	180	150	120	165	150
Ca sulfonate	0.06	0.04	0.04	0	0.05	0.05	0.06	0	0
Ca, ppm	66	43	44	0	47	51	67	0	0
Other Additives	2.53	2.48	2.48	2.19	2.36	2.34	2.53	2.27	3.42
Oil of lubricating vis	95.93	96.27	96.26	96.42	96.32	96.34	95.93	96.32	95.33
KV @40	12.82	8.4	8.3	10.18	10.21	10.2	12.84	10.27	10.14
ratio of P_phos ester/B_Borate ester	1.058201	1.851852	1.851852	1.527778	1.587302	1.322751	1.058201	1.455026	1.234568

[0145] Further formulations were blended according to the table below.

	C1	C2	C3	C4	C5	C6	C7
Dispersant (active)	2.11	0.68	0.67	0.95	0.53	0.61	0.96
ppm B from disp	111	128	58	0	16	23	0
Borate ester	0	0	0	0	0	0.42	0
ppm B from Borate ester	0	0	0	0	0	113.4	0
Borate epoxide	0.14	0.14	0.14	0.14	0.14	0.12	0.14
ppm B from Borate epox	29.4	29.4	29.4	29.4	29.4	25.2	29.4
dibutyl phosphite	0.09	0.09	0.09	0.16	0.16	0.11	0.16
C16-C18 alkenyl phosphite	0.12	0.12	0.12	0.12	0.12	0.08	0.12
phosphite ester reaction product	0.11	0.11	0.11	0.16	0.16	0.05	0.16
ppm P from phos ester	165	165	165	240	240	75	240
Ca sulfonate	0	0	0	0	0	0.06	0
Ca, ppm	0	0	0	0	0	85	0
Other Additives	2.27	2.27	2.27	2.27	2.27	2.58	2.27
Oil of lubricating vis	95.16	96.59	96.6	96.2	96.62	95.97	96.19
KV @40	11.27	10.06	10.06	10.61	9.98	12.92	10.58
ratio of P_phos ester/B_Borate ester	-	-	-	-	-	0.661376	-

[0146] The conductivity of the samples was measured using a Tettex 2830/2831 oil dielectric analyzer outfitted with a test cell for liquid insulating materials (Tettex 2903) with a 2 mm electrode spacing. 40 ml of each sample was transferred into the test cell. Dissipation factor and dielectric constant (permittivity) were recorded at 100°C ± 2°C and 600 V AC applied. The frequency was held constant at 50 Hz. Resistivity measurements were also made at this temperature at +500 V DC with a 3 minute shorting time and 1 minute electrification time. Conductivity was calculated from the final resistivity value recorded.

[0147] The samples were also tested for pitting according to an 80 hour FZG pitting test. This test uses 1500 grams of oil sample and an FZG pitting rig where the speed is set at 1,500 RPM (8.65 m/s) with an arm length of 0.5% at 120°C sump temperature. The test initially starts in load stage 7 for 8 hours and then is inspected for any wear issues. If there are no wear issues, the test is then restarted at a load stage 8 and run using the same speed and temperature for another 8 hours. After re-inspecting the gear from the second 8 hour run for any wear issues, the sample is run for an additional 64 hours at a load stage 9 with the same 1,500 RPM speed at 120°C. Once completed, each tooth on the pinion gear is inspected for the number and size (in millimeters) of micro pits using a measuring gauge. The area in millimeters of the highest micropitted tooth as well as the total of all micropits from all teeth is reported. Lower levels of pitting are preferred.

[0148] The results of the conductivity and pitting test are presented in the table below.

	1	2	3	4	5	6	7	8	9
Conductivity	4.46	2.37	3.52	5.54	4.4	4.5	4.78	5.87	3.65
FZG Pitting									
max 1 tooth (5 max)	0.12	0.12	0.24	0.5	0.5	0.75	1	1.62	2
Average all teeth (18 max)	0.12	0.12	0.72	0.5	1.22	0.75	1	1.74	2

	C1	C2	C3	C4	C5	C6	C7
Conductivty	13.4	9	7.28	8.7	8.31	5.49	8.45
FZG Pitting							
max 1 tooth (5 max)	0.24	0.5	2	4.25	9	10	27
Average all teeth (18 max)	0.24	1	4	10.37	21.12	11.49	131.5

[0149] The mention of any document is not an admission that such document qualifies as prior art or constitutes the general knowledge of the skilled person in any jurisdiction. Except in the Examples, or where otherwise explicitly indicated, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word "about." It is to be understood that the upper and lower amount, range, and ratio limits set forth herein may be independently combined. Similarly, the ranges and amounts for each element of the invention can be used together with ranges or amounts for any of the other elements.

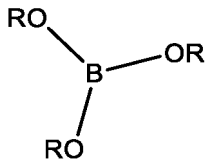
[0150] As used herein, the transitional term "comprising," which is synonymous with "including," "containing," or "characterized by," is inclusive or open-ended and does not exclude additional, un-recited elements or method steps. However, in each recitation of "comprising" herein, it is intended that the term also encompass, as alternative embodiments, the phrases "consisting essentially of' and "consisting of," where "consisting of' excludes any element or step not specified and "consisting essentially of' permits the inclusion of additional un-recited elements or steps that do not materially affect the essential or basic and novel characteristics of the composition or method under consideration.

[0151] While certain representative embodiments and details have been shown for the purpose of illustrating the subject invention, it will be apparent to those skilled in this art that various changes and modifications can be made therein without departing from the scope of the subject invention. In this regard, the scope of the invention is to be limited only by the following claims.

Claims

1. A lubricant composition for lubricating a transmission in a vehicle with an electric motor comprising

a. an oil of lubricating viscosity
b. 0.2 to 2.0 wt % of at least one borate ester of formula I,



wherein each R, independently, is a C_3 to C_{12} alkyl,
c. at least one phosphorous containing compound comprising a phosphite ester composition that comprises the reaction product of a monomeric phosphorous acid or an ester thereof with at least two alkylene diols, wherein the at least one phosphorus containing compound is present in an amount to deliver 100 to 450 ppm of phosphorus to the lubricating composition,
d. a dispersant at a total amount of 1.8 wt.% or less and delivering less than 100 ppm boron to the lubricant composition, wherein the dispersant is selected from the group consisting of succinimide dispersants prepared by the reaction of a hydrocarbyl-substituted succinic anhydride or reactive equivalent thereof with an amine; amine dispersants prepared by the reaction of high molecular weight aliphatic or alicyclic halides and amines; Mannich dispersants prepared by the reaction of alkyl phenols in which the alkyl group contains at least 30 carbon atoms with aldehydes and amines; ester dispersants prepared by reaction of a hydrocarbyl acylating

agent and a polyhydric aliphatic alcohol; and mixtures thereof, and
e. optionally a calcium containing sulfonate or salicylate detergent or mixtures thereof present in an amount to deliver 300 ppm or less calcium to the lubricating composition,

wherein the lubricant composition has a kinematic viscosity at 40°C of from 8 cSt to 18 cSt, and
wherein the ratio of phosphorous from the phosphite ester composition of (c) and the boron from the borate ester of (b) is greater than 0.7.

2. The lubricant composition of claim 1, where the phosphorous containing compound additionally comprises a C_{3-8} hydrocarbyl phosphite.

3. The lubricant composition of any of claims 1-2 further comprising 0.01 to 1.0 wt % of an ester of (1) a polyol, and 2) an aliphatic carboxylic acid containing 12 to 24 carbon atoms.

4. The lubricant composition of any of claims 1-3, wherein the ester is glycerol monooleate.

5. The lubricant composition of any of claims 1-4, further comprising 0.1 to 3.0 wt % of an ester of (1) an alcohol, and 2) an aliphatic carboxylic acid containing 4 to 8 carbon atoms.

6. The lubricant composition of any of claims 1-5, wherein the ester is a C_{8-13} adipate ester.

7. The lubricant composition of any of claims 1-6 further comprising 0.01 wt % to 0.5 wt % of a dimercaptothiadiazole.

8. The lubricant composition of any of claims 1-7 further comprising 0.1 wt % to 5 wt % of a poly(meth)acrylate ester polymer viscosity modifier.

9. The lubricant composition of claim 8, wherein the poly(meth)acrylate ester polymer has a weight average molecular weight of 5,000 to 25,000.

10. The lubricant composition of any of claims 1-9 further comprising 0.05 wt % to 1.0 wt % of a C_{12} to C_{24} hydrocarbyl phosphite.

11. The lubricant composition of any of claims 1-10 further comprising 0.01 wt % to 1.0 wt % of a C_{12-24} borated epoxide.

12. The lubricant composition of any of claims 1-11 further comprising 0.1 wt % to 3.0 wt % of a mixture of at least two antioxidants selected from hindered phenols, aryl amines, and sulfur containing antioxidants.

13. The lubricant composition of any of claims 1-12 wherein the lubricant composition exhibits an electrical conductivity of up to 7.0×10^{-10} S/cm as measured by ASTM D2624 at 100°C and 500 V.

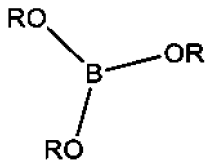
14. A method of lubricating a transmission in a vehicle with an electric motor comprising supplying to the automatic transmission a composition of any of claims 1-13, and operating the transmission, preferably wherein the transmission does not include a shifting clutch.

15. Use of a composition of any of claims 1-13 for lubricating a transmission in a vehicle with an electric motor.

Patentansprüche

1. Schmierstoffzusammensetzung zum Schmieren eines Getriebes in einem Fahrzeug mit einem Elektromotor, umfassend

a. ein Öl mit Schmierviskosität
b. 0,2 bis 2,0 Gew.-% wenigstens eines Boratesters von Formel I,



wobei jedes R unabhängig ein C_3- bis C_{12}-Alkyl ist,

c. wenigstens eine phosphorhaltige Verbindung, umfassend eine Phosphitesterzusammensetzung, die das Reaktionsprodukt einer monomeren phosphorigen Säure oder eines Esters davon mit wenigstens zwei Alkylendiolen umfasst, wobei die wenigstens eine phosphorhaltige Verbindung in einer Menge vorliegt, um 100 bis 450 ppm Phosphor zu der Schmiermittelzusammensetzung zuzuführen,

d. ein Dispergiermittel in einer Gesamtmenge von höchstens 1,8 Gew.-% und das der Schmierstoffzusammensetzung weniger als 100 ppm Bor zuführt, wobei das Dispergiermittel aus der Gruppe ausgewählt ist, die aus Folgendem besteht: Succinimiddispergiermitteln, die durch die Reaktion eines mit Hydrocarbyl substituierten Bernsteinsäureanhydrids oder eines reaktiven Äquivalents davon mit einem Amin hergestellt sind; Amindispergiermitteln, die durch die Reaktion von aliphatischen oder alicyclischen Halogeniden und Aminen mit hoher Molekülmasse hergestellt sind; Mannich-Dispergiermitteln, die durch die Reaktion von Alkylphenolen, in denen die Alkylgruppe wenigstens 30 Kohlenstoffatome enthält, mit Aldehyden und Aminen hergestellt sind; Esterdispergiermitteln, die durch die Reaktion eines Hydrocarbylacylierungsmittels und eines mehrwertigen aliphatischen Alkohols hergestellt sind; und Mischungen davon, und

e. optional ein calciumhaltiges Sulfonat- oder Salicylatdetergens oder Mischungen davon, vorliegend in einer Menge, um höchstens 300 ppm Calcium zu der Schmierzusammensetzung zuzuführen,

wobei die Schmierstoffzusammensetzung eine kinematische Viskosität bei 40 °C von 8 cSt bis 18 cSt aufweist, und wobei das Verhältnis von Phosphor aus der Phosphitester-Zusammensetzung von (c) und dem Bor aus dem Boratester von (b) größer als 0,7 ist.

2. Schmierstoffzusammensetzung nach Anspruch 1, wobei die phosphorhaltige Verbindung zusätzlich ein C_{3-8}-Hydrocarbylphosphit umfasst.

3. Schmierstoffzusammensetzung nach einem der Ansprüche 1-2, ferner umfassend 0,01 bis 1,0 Gew.-% eines Esters von (1) einem Polyol und 2) einer aliphatischen Carbonsäure, die 12 bis 24 Kohlenstoffatome enthält.

4. Schmierstoffzusammensetzung nach einem der Ansprüche 1-3, wobei der Ester Glycerinmonooleat ist.

5. Schmierstoffzusammensetzung nach einem der Ansprüche 1-4, ferner umfassend 0,1 bis 3,0 Gew.-% eines Esters von (1) einem Alkohol und 2) einer aliphatischen Carbonsäure, die 4 bis 8 Kohlenstoffatome enthält.

6. Schmierstoffzusammensetzung nach einem der Ansprüche 1-5, wobei der Ester ein C_{8-13}-Adipatester ist.

7. Schmierstoffzusammensetzung nach einem der Ansprüche 1-6, ferner umfassend 0,01 Gew.-% bis 0,5 Gew.-% eines Dimercaptothiadiazols.

8. Schmierstoffzusammensetzung nach einem der Ansprüche 1-7, ferner umfassend 0,1 Gew.-% bis 5 Gew.-% eines Poly(meth)acrylatesterpolymer-Viskositätsmodifizierers.

9. Schmierstoffzusammensetzung nach Anspruch 8, wobei das Poly(meth)acrylatesterpolymer ein Gewichtsmittel der Molekülmasse von 5.000 bis 25.000 aufweist.

10. Schmierstoffzusammensetzung nach einem der Ansprüche 1-9, ferner umfassend 0,05 Gew.-% bis 1,0 Gew.-% eines C_{12}- bis C_{24}-Hydrocarbylphosphits.

11. Schmierstoffzusammensetzung nach einem der Ansprüche 1-10, ferner umfassend 0,01 Gew.-% bis 1,0 Gew.-% eines borierten C_{12-24}-Epoxids.

12. Schmierstoffzusammensetzung nach einem der Ansprüche 1-11, ferner umfassend 0,1 Gew.-% bis 3,0 Gew.-% einer Mischung von wenigstens zwei Antioxidantien, die aus gehinderten Phenolen, Arylaminen und schwefelhaltigen

Antioxidantien ausgewählt sind.

13. Schmierstoffzusammensetzung nach einem der Ansprüche 1-12, wobei die Schmierstoffzusammensetzung wie durch ASTM D2624 bei 100 °C und 500 V gemessen eine elektrische Leitfähigkeit von bis zu $7{,}0\times10^{-10}$ S/cm vorweist.

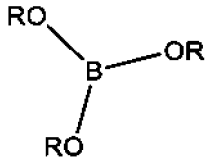
14. Verfahren zum Schmieren eines Getriebes in einem Fahrzeug mit einem Elektromotor, umfassend ein Zuleiten einer Zusammensetzung nach einem der Ansprüche 1-13 zu dem Automatikgetriebe und ein Betreiben des Getriebes, wobei das Getriebe vorzugsweise keine Schaltkupplung beinhaltet.

15. Verwendung einer Zusammensetzung nach einem der Ansprüche 1-13 zum Schmieren eines Getriebes in einem Fahrzeug mit einem Elektromotor.

Revendications

1. Composition lubrifiante destinée à lubrifier une transmission dans un véhicule à moteur électrique comprenant

a. une huile de viscosité lubrifiante ;
b. 0,2 à 2,0 % en poids d'au moins un ester borate de formule I,



où chaque R, indépendamment, représente un alkyle en C_3 à C_{12},
c. au moins un composé contenant du phosphore comprenant une composition d'ester de phosphite qui comprend le produit de réaction d'un acide phosphoreux monomère ou d'un ester de celui-ci avec au moins deux alkylène diols, dans laquelle l'au moins un composé contenant du phosphore est présent en une quantité pour délivrer 100 à 450 ppm de phosphore à la composition lubrifiante,
d. un dispersant en une quantité totale de 1,8 % en poids ou moins et délivrant moins de 100 ppm de bore à la composition lubrifiante, dans lequel le dispersant est choisi dans le groupe constitué des dispersants succinimides préparés par la réaction d'un anhydride succinique à substituant hydrocarbyle ou son réactif équivalent avec une amine ; des dispersants aminés préparés par la réaction d'halogénures et d'aminés aliphatiques ou alicycliques de haut poids moléculaire ; dispersants de Mannich préparés par réaction d'alkylphénols dans lesquels le groupe alkyle contient au moins 30 atomes de carbone avec des aldéhydes et des amines ; des dispersants esters préparés par réaction d'un agent d'acylation hydrocarbyle et d'un alcool aliphatique polyhydrique ; et leurs mélanges, et
e. éventuellement un détergent sulfonate ou salicylate contenant du calcium ou des mélanges de ceux-ci présents en une quantité pour fournir 300 ppm ou moins de calcium à la composition lubrifiante,

dans laquelle la composition lubrifiante a une viscosité cinématique à 40 °C de 8 cSt à 18 cSt, et
dans laquelle le rapport du phosphore de la composition d'ester de phosphite de (c) et du bore de l'ester de borate de (b) est supérieur à 0,7.

2. Composition lubrifiante selon la revendication 1, dans laquelle le composé contenant du phosphore comprend en outre un phosphite d'hydrocarbyle en $C_{3\text{-}8}$.

3. Composition lubrifiante selon l'une quelconque des revendications 1 à 2, comprenant en outre 0,01 à 1,0 % en poids d'un ester (1) d'un polyol, et 2) d'un acide carboxylique aliphatique contenant 12 à 24 atomes de carbone.

4. Composition lubrifiante selon l'une quelconque des revendications 1 à 3, dans laquelle l'ester est le monooléate de glycérol.

5. Composition lubrifiante selon l'une quelconque des revendications 1 à 4, comprenant en outre 0,1 à 3,0 % en poids d'un ester (1) d'un alcool, et 2) d'un acide carboxylique aliphatique contenant 4 à 8 atomes de carbone.

6. Composition lubrifiante selon l'une quelconque des revendications 1 à 5, dans laquelle l'ester est un ester adipate en C_{8-13}.

7. Composition lubrifiante selon l'une quelconque des revendications 1 à 6, comprenant en outre 0,01 % en poids à 0,5 % en poids d'un dimercaptothiadiazole.

8. Composition lubrifiante selon l'une quelconque des revendications 1 à 7, comprenant en outre 0,1 % en poids à 5 % en poids d'un modificateur de viscosité polymère d'ester poly(méth)acrylate.

9. Composition lubrifiante selon la revendication 8, dans laquelle le polymère d'ester poly(méth)acrylate a un poids moléculaire moyen en poids de 5 000 à 25 000.

10. Composition lubrifiante selon l'une quelconque des revendications 1 à 9 comprenant en outre 0,05 % en poids à 1,0 % en poids d'un phosphite d'hydrocarbyle en C_{12} à C_{24}.

11. Composition lubrifiante selon l'une quelconque des revendications 1 à 10, comprenant en outre 0,01 % en poids à 1,0 % en poids d'un époxyde borate en C_{12-24}.

12. Composition lubrifiante selon l'une quelconque des revendications 1 à 11, comprenant en outre 0,1 % en poids à 3,0 % en poids d'un mélange d'au moins deux antioxydants choisis parmi les phénols encombrés, les arylamines et les antioxydants contenant du soufre.

13. Composition lubrifiante selon l'une quelconque des revendications 1 à 12, dans laquelle la composition lubrifiante présente une conductivité électrique allant jusqu'à $7,0 \times 10^{-10}$ S/cm telle que mesurée par ASTM D2624 à 100 °C et 500 V.

14. Procédé de lubrification d'une transmission dans un véhicule avec un moteur électrique comprenant la fourniture à la transmission automatique d'une composition selon l'une quelconque des revendications 1 à 13, et le fonctionnement de la transmission, de préférence dans lequel la transmission ne comporte pas d'embrayage de changement de vitesse.

15. Utilisation d'une composition selon l'une quelconque des revendications 1 à 13 pour lubrifier une transmission dans un véhicule avec un moteur électrique.

REFERENCES CITED IN THE DESCRIPTION

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