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

(11) **EP 2 692 841 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
05.02.2014 Bulletin 2014/06

(21) Application number: **11862708.2**

(22) Date of filing: **13.09.2011**

(51) Int Cl.:
C10M 137/00 *(2006.01)* ***C10M 141/10*** *(2006.01)*
C10M 133/16 *(2006.01)* ***C10M 137/02*** *(2006.01)*
C10M 137/04 *(2006.01)* ***C10N 30/00*** *(2006.01)*
C10N 30/06 *(2006.01)* ***C10N 40/00*** *(2006.01)*
C10N 40/04 *(2006.01)*

(86) International application number:
PCT/JP2011/070814

(87) International publication number:
WO 2012/132055 (04.10.2012 Gazette 2012/40)

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

(30) Priority: **29.03.2011 JP 2011072464**

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(54) LUBRICATING OIL COMPOSITION

(57) The present invention provides a lubricating oil composition that maintains properties necessary to lubricating a transmission and other devices and has more excellent insulation properties and anti-wear properties and more improved anti-seizure properties than the prior art and comprises (A) a lubricating oil base oil; (B) at least one type of phosphorus compound selected from the group consisting of phosphorus compounds having at least one hydroxyl group and/or at least one thiol group; and (C) an ashless dispersant having a functional group containing as a dispersion group in an amount of less than 0.001 percent by mass on the basis of nitrogen on the total composition mass basis or no such an ashless dispersant at all, the composition having a 80°C volume resistivity of 5×10^8 Ω·m or greater.

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Description

Technical Field

[0001] The present invention relates to lubricating oil compositions with excellent insulation properties and lubricity.

Background Art

[0002] A variety of electronic control devices have been used in the mechanisms of an automobile. Some of them may be used in lubricating oil and thus the insulation properties thereof have become important. In particular, lubricating oils for the transmission, both the transmission and electric motor, or the device in which a lubricating system is shared by the transmission and electric motor, mounted in a fuel cell electric vehicle, an electric vehicle or a hybrid vehicle have been required to have higher insulation properties because these devices operate using a high electric voltage. Furthermore, in recent years, the transmission has been required to be improved in power transmission efficiency and downsized as well as weight-reduced so as to improve fuel efficiency and thus has been applied with a higher load. The lubricating oil has, therefore, been demanded to have insulation properties as well as more improved anti-wear properties and anti-seizure properties.

[0003] In addition to the above-described properties, the lubricating oil for transmissions are required to have friction characteristics conforming with the characteristics of a clutch, viscosity characteristics ranging from low temperatures to high temperatures so that an appropriate hydraulic pressure control can be achieved, i.e., viscosity retention which is not affected on temperature as much as possible, and oxidation stability and detergent dispersibility to keep the device clean so that the control device thereof can operate appropriately. Furthermore, these characteristics are generally needed to be retained during the working life of the device. For this purpose, a variety of additives are used in a transmission lubricating oil.

[0004] So far, as such transmission lubricating oils, some oils have been proposed such as an automobile transmission oil composition comprising a base oil selected from mineral oils, synthetic oils and mixtures thereof and a phosphorus compound selected from hydrocarbon group-containing zinc dithiophosphate, triaryl phosphate, triaryl thiophosphate and a mixture thereof in an amount of 0.1 to 15.0 percent by mass on the total mass composition basis and having a 80°C volume resistivity of 1×10^7 Ω·m or greater (Patent Literature 1) and a transmission oil composition comprising a base oil selected from mineral oils, poly-α-olefins and hydrogenated compounds thereof, alkylbenzenes, ester-based compounds and mixtures thereof and having a 80°C kinematic viscosity of 1.5 to 4.0 mm^2/s, a phosphorus compound selected from hydrocarbon group-containing zinc dithiophosphate, triaryl thiophosphates and mixtures thereof in an amount of 0.1 to 4.0 percent by mass on the total composition mass basis, and an ashless dispersant and having a 80°C volume resistivity of 1×10^8 Ω·m or greater (Patent Literature 2).

Citation List

Patent Literature

[0005]

Patent Literature 1: WO2002/097017
Patent Literature 2: Japanese Patent Application Publication 2008-285682

Summary of Invention

Technical Problem

[0006] As described above, a variety of additives are used in a transmission oil but would alone or in combination degrade the insulation properties, anti-wear properties or anti-seizure properties. The present invention aims at providing a lubricating oil composition maintaining properties necessary for a transmission and having more excellent insulation properties and anti-wear properties and more improved anti-seizure properties than the prior art.

Solution to Problem

[0007] That is, the present invention relates to a lubricating oil composition comprising: (A) a lubricating oil base oil; (B) at least one type of phosphorus compound selected from the group consisting of phosphorus compounds having at least one hydroxyl group and/or at least one thiol group; and (C) an ashless dispersant having a functional group

containing as a dispersion group in an amount of less than 0.001 percent by mass on the basis of nitrogen on the total composition mass basis or no such an ashless dispersant at all, the composition having a 80°C volume resistivity of 5×10^8 Ω·m or greater.

[0008] The present invention also relates to the above-described lubricating oil composition wherein (B) the phosphorus compound having a hydrocarbon group having 16 or fewer carbon atoms.

[0009] The present invention also relates to the above-described lubricating oil composition used for the transmission, both transmission and electric motor, or the device in which a lubricating system is shared by the transmission and electric motor, mounted in a fuel cell electric vehicle, an electric vehicle or a hybrid vehicle.

Advantageous Effects of the Invention

[0010] The lubricating oil composition of the present invention maintains properties necessary to lubricate a transmission and other devices and has more excellent insulation properties and anti-wear properties than the prior art and can be improved in anti-seizure properties.

Description of Embodiment

[0011] The present invention will be described in more detail below.

[0012] The lubricating base oil referred to as Component (A) used in the present invention may be a mineral base oil and/or a synthetic base oil or alternatively a mixture of two or more types of mineral oils or synthetic base oils, or a mixture of a mineral base oil and a synthetic base oil. The mix ratio in these mixtures may be selected arbitrarily.

[0013] Examples of the mineral lubricating base oil which may be used in the present invention include paraffinic or naphthenic mineral base oils which can be produced by subjecting a lubricating oil fraction produced by atmospheric- or vacuum-distillation of a crude oil, to any one of or any suitable combination of refining processes selected from solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrorefining, sulfuric acid treatment, and clay treatment; n-paraffins; and iso-paraffins. These base oils may be used alone or in combination at an arbitrary ratio.

[0014] Examples of preferred mineral lubricating base oils include the following base oils:

(1) a distillate oil produced by atmospheric distillation of a paraffin base crude all and/or a mixed base crude oil;
(2) a whole vacuum gas oil (WVGO) produced by vacuum distillation of the topped crude of a paraffin base crude oil and/or a mixed base crude oil;
(3) a wax produced by a lubricating oil dewaxing process and/or a Fischer-Tropsch wax produced by a GTL process;
(4) an oil produced by mild-hydrocracking (MHC) one or more oils selected from oils of (1) to (3) above;
(5) a mixed oil of two or more oils selected from (1) to (4) above;
(6) a deasphalted oil (DAO) produced by deasphalting an oil of (1), (2) (3), (4) or (5);
(7) an oil produced by mild-hydrocracking (MHC) an oil of (6); and
(8) a lubricating oil produced by subjecting a mixed oil of two or more oils selected from (1) to (7) used as a feed stock and/or a lubricating oil fraction recovered therefrom to a normal refining process and further recovering a lubricating oil fraction from the refined product.

[0015] No particular limitation is imposed on the normal refining process used herein. Therefore, there may be used any refining process having been conventionally used upon production of a lubricating base oil. Examples of the normal refining process include (a) hydro-refining processes such as hydrocracking and hydrofinishing, (b) solvent refining such as furfural extraction, (c) dewaxing such as solvent dewaxing and catalytic dewaxing, (d) clay refining with acidic clay or active clay and (e) chemical (acid or alkali) refining such as sulfuric acid treatment and sodium hydroxide treatment. In the present invention, any one or more of these refining processes may be used in any combination and order.

[0016] The mineral lubricating base oil used in the present invention is particularly preferably a base oil produced by further subjecting a base oil selected from (1) to (8) described above to the following treatments.

[0017] That is, preferred are a hydrocracked mineral oil and/or wax-isomerized isoparaffinic base oil produced by hydrocracking or wax-isomerizing a base oil selected from (1) to (8) described above as it is or a lubricating fraction recovered therefrom and subjecting the resulting product as it is or a lubricating fraction recovered therefrom to dewaxing such as solvent dewaxing or catalytic dewaxing, followed by solvent refining or followed by solvent refining and then dewaxing such as solvent dewaxing or catalytic dewaxing. The hydrocracked mineral oil and/or wax-isomerized isoparaffinic base oil are used in an amount of preferably 30 percent by mass or more, more preferably 50 percent by mass or more, and particularly preferably 70 percent by mass or more, on the total base oil mass basis.

[0018] The lubricating base oil referred to as Component (A) used in the transmission lubricating oil composition of the present invention is a lubricating base oil adjusted so that the 100°C kinematic viscosity is from 1.5 to 4.5 mm^2/s.

[0019] Component (A) is preferably one or more types selected from the following (A-a) to (A-c):

(A-a) a mineral base oil having a 100°C kinematic viscosity of between 1.5 and lower than 3.5 mm^2/s, preferably 1.9 to 3.2 mm^2/s;
(A-b) a mineral base oil having a 100°C kinematic viscosity of between 3.5 and lower than 7 mm^2/s, preferably 3.6 to 4.5 mm^2/s; and
(A-c) a synthetic base oil having a 100°C kinematic viscosity of between 1.5 and lower than 7 mm^2/s, preferably 3.8 to 4.5 mm^2/s.

[0020] Mineral base oils (A-a) to (A-b) have a $\%C_A$ of preferably 2 or less, more preferably 1 or less, more preferably 0.5 or less, particularly preferably substantially 0. Lubricating oil (A-c) has a $\%C_A$ of substantially 0. The use of lubricating base oil (A) having a $\%C_A$ of 2 or less renders it possible to produce a lubricating oil composition with an excellent oxidation stability.

[0021] The $\%C_A$ used herein denotes the percentage of the aromatic carbon number in the total carbon number, determined in accordance with ASTM D 3238-85.

[0022] No particular limitation is imposed on the viscosity index of lubricating base oils (A-a) to (A-c), which is, however, preferably 80 or greater, more preferably 100 or greater, particularly preferably 120 or greater and usually 200 or less, preferably 160 or less. The use of a lubricating base oil having a viscosity index of greater than 80 renders it possible to produce a composition exhibiting excellent viscosity characteristics from low temperatures to high temperatures. The use of a lubricating base oil having a too high viscosity index results in a too much normal paraffins in the resulting composition and also deteriorates the low temperature fluidity thereof.

[0023] No particular limitation is imposed on the sulfur content of mineral base oils (A-a) to (A-b) used in the present invention, which is, however, preferably 0.05 percent by mass or less, more preferably 0.02 percent by mass or less, particularly preferably 0.005 percent by mass or less. The sulfur content of lubricating base oil (A-c) is substantially 0%. Reduction of the sulfur content of Component (A) renders it possible to produce a composition having a more excellent oxidation stability.

[0024] In the present invention, any one or more of the above-described base oils (A-a) to (A-c) may be used. Above all, preferably (A-a) and (A-b)and/or(A-c) are used in combination. When Component (A-a) and/or Component (A-b) and Component (A-c) are used in combination, the content of Component (A-c) is preferably 1 to 50 percent by mass, more preferably 3 to 20 percent by mass, more preferably 3 to 10 percent by mass on the total base oil mass basis. In particular, blending of Component (A-c) in an amount of on the order of 3 to 10 percent by mass renders it possible to produce a composition exhibiting excellent effects in fatigue life, low temperature characteristics, and oxidation stability at a low cost.

[0025] Lubricating base oil (A) used in the present invention has a 100°C kinematic viscosity of preferably 1.5 to 4.5 mm^2/s, more preferably 2.8 to 4.0 mm^2/s, particularly preferably 3.6 to 3.9 mm^2/s. The use of a lubricating base oil with a 100°C kinematic viscosity of 4.5 mm^2/s or lower renders it possible to produce a lubricating oil composition having a smaller frictional resistance at lubricating sites because of its small fluid resistance and thus having excellent low temperature viscosity (for example, the -40°C Brookfield viscosity is 20,000 Pa·s or less). The use of a lubricating base oil with a 100°C kinematic viscosity of 1.5 mm^2/s or higher renders it possible to produce a lubricating oil composition which is sufficient in oil film formation and thus more excellent in lubricity and less in evaporation loss of the base oil under elevated temperature conditions.

[0026] The synthetic oil referred to as (A-c) may be a synthetic lubricating oil such as poly-α-olefins (1-octene oligomer, 1-decene oligomer, ethylene-propylene cooligomer) and hydrogenated compounds thereof; isobutene oligomers and hydrogenated compounds thereof; isoparaffins; alkylbenzenes; alkylnaphthalenes; alkyldiphenyl ethanes; monoisopropyl biphenyl; dimethyl silicone; diesters (ditridecyl glutarate, di-2-ethylhexyl adipate, diisodecyl adipate, ditridecyl adipate and di-2-ethylhexyl sebacate); polyol esters (trimethylolpropane caprylate, trimethylolpropane pelargonate, pentaerythritol 2-ethylhexanoate and pentaerythritol pelargonate); polyoxyalkylene glycols; dialkyldiphenyl ethers; polyphenyl ethers; or a mixture thereof. Among these oils, preferably used are poly-α-olefins and hydrogenated compounds thereof; isobutene oligomers and hydrogenated compounds thereof; isoparaffins; alkylbenzenes; alkylnaphthalenes; alkyldiphenylethane; monoisopropyl biphenyl; and dimethyl silicone because they have a 80°C volume resistivity of 1×10^{13} Ω·m or greater and thus can enhance the insulation properties of the resulting lubricating oil composition. In general, ester-based compounds have a 80°C volume resistivity of on the order of 1×10^{9} to 1×10^{13} Ω·m and are preferably those from which the remaining moisture and impurities have been sufficiently removed.

[0027] The term "80°C volume resistivity" used herein is measured in accordance with JIS C 2101 24.(volume resistivity test).

[0028] The synthetic oil used in the present invention is preferably selected from poly-α-olefins and hydrogenated compounds thereof, alkylbenzenes, ester-based compounds and mixtures thereof. In this case, the resulting composition can maintain low temperature fluidity and low volatility in well-balance under the conditions where it is used.

[0029] Typical examples of poly-α-olefins include oligomers or cooligomers of α-olefins having 2 to 32, preferably 6

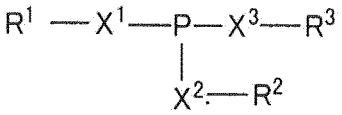
to 16 carbon atoms, such as 1-octene oligomer, 1-decene oligomer, ethylene-propylene cooligomer, and hydrogenated compounds thereof.

[0030] These synthetic oils may be used alone. No particular limitation is imposed on the viscosity thereof. However, synthetic oils with different viscosities may be used in combination so that the 100°C kinematic viscosity is adjusted to preferably from 1.5 to 4.5 mm^2/s. This is because the combination of a synthetic oil having a high viscosity with that of a low viscosity results in a base oil having a higher viscosity index.

[0031] The lubricating oil base oil referred to as Component (A) in the present invention is as described above but is preferably mixed with a solvent refined base oil having a kinematic viscosity of 20 mm^2/s to 50 mm^2/s if the resulting composition has a problem in fatigue life. Furthermore, it is preferably mixed with such a solvent refined oil in such an extent that the mixture is adjusted to have a $\%C_A$ of 2 or less and a 100°C kinematic viscosity of 1.5 to 4.5 mm^2/s.

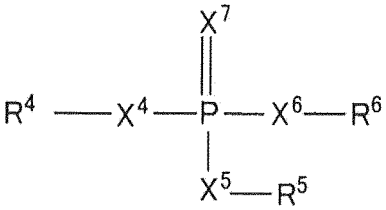
[0032] The lubricating oil composition of the present invention contains (B) at least one type of phosphorus compound selected from phosphorus compounds having at least one hydroxyl group and/or at least one thiol group.

[0033] The phosphorus compound referred to as Component (B) in the present invention is at least one type of compound selected from phosphorus compounds represented by formula (1), phosphorus compounds represented by formula (2), amine salts thereof, and derivatives thereof.



(1)

[0034] In formula (1), X^1, X^2 and X^3 are each independently oxygen or sulfur and at least one of them is preferably oxygen, at least one of R^1, R^2 and R^3 is hydrogen and the others are hydrocarbon groups having 1 to 30 carbon atoms.



(2)

[0035] In formula (2), X^4, X^5, X^6 and X^7 are each independently oxygen or sulfur (one or two of X^4, X^5 and X^6 may be a single bond or (poly) oxyalkylene group) and at least one of them is preferably oxygen, at least one of R^4, R^5 and R^6 is hydrogen and the others are hydrocarbon groups having 1 to 30 carbon atoms.

[0036] Examples of the hydrocarbon groups having 1 to 30 carbon atoms for R^1 to R^6 include alkyl, cycloalkyl, alkenyl, alkyl-substituted cycloalkyl, aryl, alkyl-substituted aryl, and arylalkyl groups. The hydrocarbon groups are preferably alkyl groups having 1 to 30 carbon atoms and aryl groups having 6 to 24 carbon atoms, more preferably alkyl groups having 3 to 18 carbon atoms, more preferably alkyl groups having 4 to 12 carbon atoms.

[0037] Examples of phosphorus compounds represented by formula (1) include phosphorous acid; monothiophosphorous acid; dithiophosphorous acid; phosphorous acid monoesters, monothiophosphorous acid monoesters, dithiophosphorous acid monoesters, and trithiophosphorous acid monoesters, each having any one of the above-described hydrocarbon groups having 1 to 30 carbon atoms; and phosphorous acid diesters, monothiophosphorous acid diesters, dithiophosphorous acid diesters, and trithsophosphorous acid diesters, each having any two of the above-described hydrocarbon groups having 1 to 30 carbon atoms; and a mixture thereof.

[0038] In order to further enhance the properties such as high temperature detergency and oxidation stability in the present invention, preferably two or more, particularly preferably all of X^1 to X^3 in formula (1) are oxygen.

[0039] Examples of phosphorus compounds represented by formula (2) include phosphoric acid; monothiophosphoric acid; dithiophosphoric acid; trithiophosphoric acid; tetrathiophosphoric acid; phosphoric acid monoesters, monothiophospharic acid monoesters, dithiophosphoric acid monoesters, trithiophosphoric acid monoesters, and tetrathiophosphoric acid monoesters, each having any one of the above-described hydrocarbon groups having 1 to 30 carbon atoms; phosphoric acid diesters, monothiophosphoric acid diesters, dithiophosphoric acid diesters, trithiophosphoric acid diesters, and tetrathiophosphoric acid diesters, each having any two of the above-described hydrocarbon groups having 1 to 30 carbon atoms; phosphonic acid, phosphonic acid monoesters, and phosphonic acid diesters, each having any one or two of the above-described hydrocarbon groups having 1 to 30 carbon atoms; the phosphoric acid compounds exemplified above but having a (poly)oxyalkylene group having 1 to 4 carbon atoms; derivatives of the phosphorus compounds exemplified above, such as β-dithiophosphorylated propionic acid and reaction products of dithiophosphates and olefin cyclopentadiene or (methyl)methacrylates; and mixtures thereof.

[0040] In order to further enhance the properties such as high temperature detergency and oxidation stability in the present invention, preferably two or more, more preferably three or more, particularly preferably all of X^4 to X^7 in formula (2) are oxygen. One or two of X^4, X^5 and X^6 may be a single bond or a (poly)oxyalkylene group.

[0041] Examples of the salts of phosphorus compounds represented by formula (1) or (2) include salts produced by allowing a nitrogen compound such as ammonia or an amine compound having in its molecules only a hydrocarbon group having 1 to 30 carbon atoms or a hydroxyl group-containing hydrocarbon group having 1 to 30 carbon atoms to react with a phosphorus compound and neutralize the whole or part of the remaining acid hydrogen.

[0042] Specific examples of the nitrogen-containing compound include ammonia, monoamines, diamines, and polyamines. Preferred examples include aliphatic amines having an alkyl or alkenyl group having 10 to 20 carbon atoms, which may be straight-chain or branched, such as decylamine, dodecylamine, dimethyldodecylamine, tridecylamine, heptadecylamine, octadecylamine, oleylamine, and stearyl amine.

[0043] The phosphorus compound referred to as Component (B) is preferably at least one type of compound selected from the group consisting of amine salts of phosphorus compounds of formula (1) wherein all of X^1, X^2 and X^3 are oxygen and amine salts of phosphorus compounds of formula (2) wherein all of X^4, x^5, X^6 and X^7 are oxygen (one or two of X^4, and X^6 may be a single bond or a (poly) oxyalkylene group) because they are excellent in oxidation stability.

[0044] Alternatively, the phosphorus compound referred to as Component (B) is preferably a phosphorus compound of formula (2) wherein all of X^4, X^5, X^6 and X^7 are oxygen (one or two of X^4, X^5 and X^6 may be a single bond or a (poly) oxyalkylene group), at least one of R^4, R^5 and R^6 is hydrogen and the others are each independently a hydrocarbon group having 1 to 30 carbon atoms in terms of oxidation stability.

[0045] The hydrocarbon group of the phosphorus compound referred to as Component (B) has preferably 16 or fewer carbon atoms. This is based on the fact that fewer the carbon atoms, higher the volume resistivity is as set forth in Table 1 below.

[0046]

[Table 1]

Structure of phosphorus compound	Trialkyl phosphite			Dialkylhydrogen phosphine			Diphenylhydrogen phosphine	Dialkyl acid phosphate	
Structure of hydrocarbon group	iC8	nC12	nC18	iC4	iC8	nC18	phenyl	nC10	nC18
Carnbon number of hydrocarbon group	8	12	18	4	8	18	6	10	18
Volume resistivity 10^{10} Ω·m	358	315	27.9	1200	104	12.8	800	1.44	1.4
*Phosphoric compounds were each dissolved in a base oil with the following physical properties to compare the volume resistivity. They were each added in an amount of 100 mass ppm by phosphorus. Kinematic viscosity (40°C) 19.7mm^2/s, Kinematic viscosity (100°C) 4.3mm^2/s, Viscosity index 125, $\%C_P$ 78.5, $\%C_N$21.5, $\%C_A$0									

[0047] In Table 1, the volume resistivity designates the value measured at an oil temperature of 80°C in accordance with JIS C 2101 24. (volume resistivity test). In the above examples, each of the phosphorus compound was added and dissolved in a mineral base oil so that it is contained in an amount of 100 mass ppm on the basis of phosphorus.

[0048] No particular limitation is imposed on the content of Component (B) that is the above-described phosphorus compound of the lubricating oil composition of the present invention, which is, however, 0.01 percent by mass or more, preferably 0.02 percent by mass or more, particularly preferably 0.03 percent by mass or more and preferably 0.1 percent by mass or less, more preferably 0.08 percent by mass or less, particularly preferably 0.05 percent by mass or less on the basis of phosphorus on the composition mass basis. If the content of the phosphorus compound is less than 0.01 percent by mass on the basis of phosphorus, the resulting composition would be less effective in anti-wear properties. Whilst, if the content of the phosphorus compound is more than 0.1 percent by mass on the basis of phosphorus, the resulting composition would be poor in insulation properties, degraded in oxidation stability and enhanced in aggressivity

against sealing materials.

[0049] The lubricating oil composition of the present invention is characterized in that it contains (C) an ashless dispersant having a functional group containing nitrogen as a dispersion group in an amount of less than 0.001 percent by mass on the basis of nitrogen on the composition mass basis or does not contain such an ashless dispersant at all.

[0050] As described above, the lubricating oil composition of the present invention contains (B) at least one type of phosphorus compound selected from phosphorus compounds having at least one hydroxyl group and/or at least one thiol group. The inclusion of the phosphorus compound enhances significantly the anti-wear properties and anti-seizure properties of the composition. However, this type of phosphorus compound degrades drastically the volume resistance of the composition compared with a phosphorus compound having no hydroxyl group and/or thiol group if an ashless dispersant having a functional group containing nitrogen as a dispersion group is contained. Therefore, the composition contains necessarily (C) an ashless dispersant having a functional group containing nitrogen as a dispersion group in an amount of less than 0.001 percent by mass on the basis of nitrogen on the composition mass basis or does not contain such an ashless dispersant at all in order to improve the anti-wear properties and anti-seizure properties of the composition.

[0051] Examples of the ashless dispersant having a functional group containing nitrogen as a dispersion group referred to as Component (C) include succinimide, benzylamine, and polyamines, each having a hydrocarbon group having 40 to 400 carbon atoms.

[0052] However, among these compounds, those having been modified to have a structure wherein nitrogen cannot constitute a salt structure together with Component (B) that is the phosphorus compound are excluded from the examples. Fox example, compounds wherein the amino group is acylated or modified with a boron compound or a sulfuric compound and incapable of constituting a salt structure with Component (B) that is the phosphorus compound are excluded.

[0053] What is meant by "containing an ashless dispersant having a functional group containing nitrogen as a dispersion group in an amount of less than 0.001 percent by mass on the basis of nitrogen on the composition mass basis" is a structure or amount wherein even though an ashless dispersant has an amino group remained so as to be able to constitute a salt structure with Component (B) that is the phosphorus compound, the content thereof is such a level that the volume resistance at 80°C of the resulting composition is 5×10^8 Ω·m or greater. Specifically, the ashless dispersant is contained in such an amount that nitrogen is contained in an amount of less than 0.001 percent by mass, more preferably less than 0.0008 percent by mass on the composition mass basis.

[0054] No particular limitation is imposed on the use of compounds with a structure of thiadiazole or triazole that is an amine-based anti-oxidant or a corrosion inhibitor because it can be ignored if the content thereof is 1 percent by mass or less.

[0055] The lubricating oil composition of the present invention has a 80°C volume resistivity of preferably 5×10^8 Ω·m or greater, more preferably 6×10^8 Ω·m or greater, particularly preferably $10\text{x}10^8$ Ω·m or greater. The composition having a 80°C volume resistivity of 5×10^8 Ω·m or greater can keep the insulation properties high not only when it is fresh but also when it is degraded thereby avoiding an electric motor from having a trouble such as shorting out for a long period of time.

[0056] If necessary, the lubricating oil composition of the present invention may be blended with various additives such as viscosity index improvers, extreme pressure additives, dispersants other than the above-described dispersant compounds, metallic detergents, friction modifiers, anti-oxidants, corrosion inhibitors, rust inhibitors, demulsifiers, metal deactivators, pour point depressants, seal swelling agents, anti-foaming agents, and dyes, alone or in combination in order to further enhance the properties of the composition or impart the composition with properties required for a lubricating oil.

[0057] Examples of the viscosity index improvers include non-dispersant or dispersant type poly(meth)acrylate; non-dispersant or dispersant type ethylene-α-olefin copolymers and hydrogenated compounds thereof; polyisobutylene and hydrogenated compounds thereof; styrene-diene hydrogenated copolymers; styrene-maleic anhydride ester copolymers; polyalkylstyrenes; and copolymers of (meth) acrylate monomers represented by formula (1) and unsaturated monomers such as ethylene/propylene/styrene/maleic anhydride.

[0058] The amount of the viscosity index improver in the lubricating oil composition of the present invention is such an amount that the resulting composition has a 100°C kinematic viscosity of 5 to 10 mm^2/s, preferably 6 to 9 mm^2/s and a viscosity index of 120 to 270, preferably 150 to 250, more preferably 170 to 220. More specifically, the amount is 15 percent by mass or less, preferably 10 percent by mass or less, more preferably 8 percent by mass or less and 2 percent by mass or more, preferably 4 percent by mass or more, more preferably 5 percent by mass or more on the composition mass basis. An amount of more than 15 percent by mass causes a too high viscosity while an amount of less than 2 percent by mass causes a too high viscosity and thus cannot secure a sufficient composition viscosity.

[0059] Examples of the metallic detergent include those such as alkaline earth metal sulfonates, alkaline earth metal phenates, and alkaline earth metal salicylates.

[0060] Any one or more compounds selected from these metallic detergents may be contained in an amount of usually 0.01 to 10 percent by mass, preferably 0.1 to 5 percent by mass on the total composition mass basis.

[0061] The friction modifier may be any compound that has been generally used as a friction modifier for lubricating oils. Specific examples include amine compounds, imide compounds, fatty acid esters, fatty acid amides, and fatty acid metal salts, each having per molecule at least one alkyl or alkenyl group having 6 to 30 carbon atoms, particularly a straight-chain alkyl or alkenyl group having 6 to 30 carbon atoms.

[0062] Any one or more compounds selected from these friction modifiers may be contained in an amount of usually 0.01 to 5.0 percent by mass, preferably 0.03 to 3.0 percent by mass on the total composition mass basis.

[0063] The anti-oxidant may be any anti-oxidant that has been usually used in lubricating oils, such as phenol- or amine-based compounds.

[0064] Specific examples of the anti-oxidant include alkylphenols such as 2-6-di-tert-butyl-4-methylphenol; bisphenols such as methylene-4,4-bisphenol(2,6-di-tert-butyl-4-methylphenol); naphthylamines such as phenyl-α-naphthylamine; dialkyldiphenylamines; zinc dialkyldithiophosphoric acids such as di-2-ethylhexyldithiophosphoric acid; and esters of (3,5-di-tert-butyl-4-hydroxyphenyl)fatty acid (propionic acid) or (3-methyl-5-tert-butyl-4-hydroxyphenyl)fatty acid (propionic acid) with a monohydric or polyhydric alcohol such as methanol, octanol, octadecanol, 1,6-hexanediol, neopentyl glycol, thiodiethylene glycol, triethylene glycol and pentaerythritol.

[0065] Any one or more of compounds selected from these compounds may be contained in any amount, which is, however, usually from 0.01 to 5 percent by mass, preferably from 0.1 to 3 percent by mass on the total composition mass basis.

[0066] Examples of the corrosion inhibitor include benzotriazole-, tolyltriazole-, thiadiazole-, and imidazole-types compounds.

[0067] Examples of the rust inhibitor include petroleum sulfonates, alkylbenzene sulfonates, dinonylnaphthalene sulfonates, alkenyl succinic acid esters, and polyhydric alcohol esters.

[0068] Examples of the demulsifier include polyalkylene glycol-based non-ionic surfactants such as polyoxyethylene-alkyl ethers, polyoxyethylenealkylphenyl ethers, and polyoxyethylenealkylnaphthyl ethers.

[0069] Examples of the metal deactivator include imidazolines, pyrimidine derivatives, alkylthiadiazoles, mercaptobenzothiazoles, benzotriazoles and derivatives thereof, 1,3,4-thiadiazolepolysulfide, 1,3,4-thiadiazolyl-2,5-bisdialkyldithiocarbamate, 2-(alkyldithio)benzoimidazole, and β-(o-carboxybenzylthio)propionitrile.

[0070] The pour point depressant may be any of the known pour point depressants selected depending on the type of lubricating base oil but are preferably poly(meth)acrylates having a weight average molecular weight of preferably 20, 000 to 500,000, more preferably 50,000 to 300,000, particularly preferably 80,000 to 200,000.

[0071] The anti-foaming agent may be any compound that has been usually used as an anti-foaming agent for lubricating oils. Examples of such an anti-foaming agent include silicones such as dimethylsilicone and fluorosilicone. Any one or more of compounds selected from these compounds may be contained in any amount.

[0072] The seal swelling agent may be any compound that has been usually used as a seal swelling agent for lubricating oils. Examples of such a seal swelling agents include ester-, sulfur- and aromatic-based seal swelling agents.

[0073] The dye may be any compound that has been usually used and may be blended in any amount. The amount is usually from 0.001 to 1.0 percent by mass on the total composition mass basis.

[0074] When these additives are blended with the lubricating oil composition of the present invention, the corrosion inhibitor, rust inhibitor, and anti-foaming agent are each contained in an amount of 0.005 to 5 percent by mass, the pour point depressant and metal deactivator are each contained in an amount of 0.005 to 2 percent by mass, the seal swelling agent is contained in an amount of 0.01 to 5 percent by mass, and the anti-foaming agent is contained in an amount of 0.0005 to 1 percent by mass, all on the total composition mass basis.

Examples

[0075] The present invention will be described more specifically with reference to the following Examples and Comparative Examples but not limited thereto.

[0076] (Examples 1 to 6 and Comparative Examples 1 to 5)

[0077] Lubricating oil compositions according to the present invention (Examples 1 to 6) and those for comparison (Comparative Examples 1 to 5) were prepared in accordance with the formulations set forth in Table 2. The performances of each composition were evaluated with the following tests. The results are set forth in Table 2.

[Table 2]

Base Oil	Total Base Oil Mass Basis		Example	Example 2	Example 3	Example 4	Example 5	Example 6	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
A-1	Base Oil 1 [1)]	inmass %	100	100			100	100	100	100	100	100	100
A-2	Base Oil 2 [2)]	inmass %			100								
A-3	Base Oil 3 [3)]	inmass %				100							
Additives	Total Composition Mass Basis	mass %											
B-1	Oil soluble phosphorus additive 1 [4)]	mass %	0.5	0.1	0.1	0.1				0.1		0.1	
B-2	Oil soluble phosphorus additive 2 [5)]	mass %					0.1						
B-3	Oil soluble phosphorus additive 3 [6)]	mass %						0.1					
B-4	Oil soluble phosphorus additive 4 [7)]												0.3
C-1	Ashless dispersant 1 [8)]	mass %								4	4		

(continued)

Additives	Total Composition Mass Basis	mass %										
C-2	Ashless dispersant 2 [9)]										4	
D-1	Viscosity index improver [10)]	mass %	12	12	12	17	12	12	12	12	12	12	12
	Additive package [11)]	mass %	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	25	2.5	2.5
P content of the composition		massp m	500	100	100	100	100	100	0	100	0	100	100
Evalution results Four - ball test [12)]													
WL		mm^2/s	1961	1961	1961	1961	1961	1961	1961	1961	1961	1961	1961
LNSL		%	785	785	785	785	785	785	490	785	490	785	785
Four- ball (wear scar diameter) [13)]		mm^2/s	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.5	0.8	0.5	0.5

(continued)

Additives	Total Composition Mass Basis	mass %										
Volume resistivity [14]		10^{10} Ω·m	0.06	0.15	0.12	0.06	0.13	0.05	0.16	0.005	0.031	0.001	0.01

1) kinematic viscosity (40°C) 19.7mm^2/s. kinematic viscosity (100°C) 4.3mm^2/s, viscosity index 125, %C_P 78.5, %C_N 21.5, %C_A 0
2) kinematic viscosity (40°C) 22.7mm^2/s, kinematic viscosity (100°C) 4.3mm^2/s, viscosity index 102, %C_P 66.4, %C_N 29.0, %C_A4.6
3) di-2-ethylhexyl azelate kinematic viscosity (40°C) 10.1mm^2/s. kinematic viscosity (100°C) 3.0mm^2/s, viscosity index 144
4) amine salt of acidic phosphoric acid ester (P content: 10%, phosphoric acid ester: 2-ethylhexyl, amine: mixed amine of C11 to 14)
5) hydrogen phosphine, isoC4 P content 16%
6) acidic phosphoric acid ester, 2-ethylhexyl P: 9.4%
7) trioleylphosphite P: 3.7%
8) boronated succinimide, PIS M_w 2000, bis type, TEPA crosslinking
9) succinimide, PIB M_w 1000, bis type. TEPA crosslinking
10) non-dispersant type PMA M_w 25,000
11) containing Ca metallic detergent (0.1 mass%), metal deactivator (0.1 mass%), anti-oxidant (2.0 mass%), anti-foaming agent (30 mass ppm)
12) 1800 rpm
13) 392 N, 1800 rpm, 80°C, 30 min
14) in accordance with JIS C2101, measured at 80°C

Applicability in Industry

[0078] The lubricating oil composition of the present invention is a composition improved in anti-wear properties and anti-seizure properties and can be used as a lubricating oil for an electric motor-equipped vehicle such as an electric vehicle or a hybrid vehicle, an electric motor oil, an oil both for a transmission and an electric motor, and an oil for a device wherein a transmission and an electric motor are packaged in one and a lubricating system is shared by the transmission and an electric motor.

[0079] The present invention can provide the above-described transmission, electric motor and device including the lubricating oil composition of the present invention and a method for lubricating, insulating and cooling the above-described transmission, electric motor and device using the lubricating oil composition of the present invention.

Claims

1. A lubricating oil composition comprising:

(A) a lubricating oil base oil;
(B) at least one type of phosphorus compound selected from the group consisting of phosphorus compounds having at least one hydroxyl group and/or at least one thiol group; and
(C) an ashless dispersant having a functional group containing as a dispersion group in an amount of less than 0.001 percent by mass on the basis of nitrogen on the total composition mass basis or no such an ashless dispersant at all, the composition having a 80°C volume resistivity of 5×10^8 Ω·m or greater.

2. The lubricating oil composition according to claim 1 wherein (B) the phosphorus compound having a hydrocarbon group having 16 or fewer carbon atoms.

3. The lubricating oil composition according to claim 1 or 2 wherein the composition is used for the transmission, both transmission and electric motor, or the device in which a lubricating system is shared by the transmission and electric motor, mounted in a fuel cell electric vehicle, an electric vehicle or a hybrid vehicle.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/070814

A. CLASSIFICATION OF SUBJECT MATTER
C10M137/00(2006.01)i, *C10M141/10*(2006.01)i, *C10M133/16*(2006.01)n, *C10M137/02*(2006.01)n, *C10M137/04*(2006.01)n, *C10N30/00*(2006.01)n, *C10N30/06*(2006.01)n, *C10N40/00*(2006.01)n, *C10N40/04*(2006.01)n
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10M101/00-177/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2002/097017 A1 (Nissan Motor Co., Ltd. et al.), 05 December 2002 (05.12.2002), claims; page 16; examples & JP 2008-285682 A & US 2004/0209786 A1 & EP 1405897 A1	1-3
X	JP 2008-195942 A (Infinum International Ltd.), 28 August 2008 (28.08.2008), claims; examples & US 2008/0194442 A1 & EP 1964911 A2 & KR 10-2008-0075793 A	1-3

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 December, 2011 (09.12.11)	20 December, 2011 (20.12.11)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/070814

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2000-256692 A (Idemitsu Kosan Co., Ltd.), 19 September 2000 (19.09.2000), claims; examples & US 6878677 B1 & EP 1167495 A1 & WO 2000/053704 A1	1,2
X	JP 9-137181 A (Kao Corp.), 27 May 1997 (27.05.1997), claims; examples (Family: none)	1,2
X	JP 2000-109869 A (Nippon Mitsubishi Oil Corp.), 18 April 2000 (18.04.2000), claims; examples (Family: none)	1,2
P,X	WO 2011/080970 A1 (Idemitsu Kosan Co., Ltd.), 07 July 2011 (07.07.2011), claims; examples (Family: none)	1-3

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2002097017 A **[0005]**
- JP 2008285682 A **[0005]**