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(54) LUBRICATING OIL COMPOSITION

(57) A lubricating oil composition comprising: (A) a lubricating base oil; (B) an extreme pressure agent; and (C) a nitrogen-containing ashless dispersant, wherein a volume resistivity at 80°C of the lubricating oil composition is 0.0020×10^{12} Ωcm or more, the component (B) contains a specific (B1) phosphorus-based extreme pressure agent and does not contain (B2) a sulfur-containing extreme pressure agent or contains the component (B2) such that the content of sulfur derived from the component (B2) becomes a specific amount or less, a content of phosphorus derived from the component (B1) is a specific amount or less, and a mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) is 0.60 or more and 2.30 or less.

Description

[Technical Field]

[0001] The present invention relates to a lubricating oil composition.

[Background Art]

[0002] In recent years, electric vehicles that do not emit carbon dioxide, which is a greenhouse gas, have been attracting attention. Such electric vehicles usually use electric motors as power sources for traveling and are provided with gear mechanisms such as transmissions. Conventionally, different lubricating oil compositions have been used for cooling and lubricating such electric motors and for lubricating gear mechanisms; however, in recent years, it has come to be proposed that the same lubricating oil composition is used in order to simplify the circulation mechanism of the lubricating oil composition. Particularly, in the case where an electric vehicle has a unified structure of an electric motor and a transmission, the use of the same lubricating oil composition is required for lubrication of the electric motor and the transmission. Under these circumstances, various lubricating oil compositions for electric vehicles have been studied.

[0003] For example, Japanese Unexamined Patent Application Publication No. 2019-137829 (PTL 1) discloses a lubricating oil composition comprising: (A) a lubricating base oil; (B1) a phosphite ester having at least one alkyl group having 4 to 10 carbon atoms or an amine salt thereof; (C) a borate ester; (D) a sulfur-based extreme pressure agent; and (E) an organic friction modifier, wherein the lubricating oil composition has a kinematic viscosity at 100°C of 1.5 to 5 mm^2/s, a phosphorus content of 310 to 1000 ppm, a boron content of 50 to 400 ppm, and a sulfur content of 250 to 1000 ppm relative to the mass of the lubricating oil composition.

[0004] In addition, Japanese Unexamined Patent Application Publication No. 2020-066673 (PTL 2) discloses a lubricating oil composition comprising: a base oil (A); a neutral phosphorus-based compound (B); an acidic phosphorus-based compound (C); a sulfur compound (D); and a metal salt (E) selected from a metal sulfonate, a metal salicylate, and a metal phenate, wherein the content of the acidic phosphorus-based compound (C) in terms of phosphorus atoms is 10 to 180 mass ppm based on the total amount of the lubricating oil composition, the content of the sulfur compound (D) in terms of sulfur atoms is 10 to 1000 mass ppm based on the total amount of the lubricating oil composition, and the content of the metal salt (E) in terms of metal atoms is 5 to 180 mass ppm based on the total amount of the lubricating oil composition.

[Citation List]

[Patent Literature]

[0005]

[PTL 1] Japanese Unexamined Patent Application Publication No. 2019-137829
[PTL 2] Japanese Unexamined Patent Application Publication No. 2020-066673

[Summary of Invention]

[Technical Problem]

[0006] However, while lubrication of an electric motor and a transmission of an electric vehicle needs to simultaneously achieve high insulation properties, high oxidation stability, and high extreme pressure resistance (extreme pressure resistance based on seizure resistance (load-carrying capacity) and anti-wear performance (wear resistance)), conventional lubricating oil compositions as described in PTLs 1 and 2 have not been able to achieve all of these properties at a high level, namely insulation properties, oxidation stability, and extreme pressure resistance. In recent years, electric motors are required to be used at a higher voltage and gears and bearings are also required to be used under more severe conditions in order to obtain a higher motor output, and thus there has been a demand for a lubricating oil composition that has well-balanced insulation properties, oxidation stability, and extreme pressure resistance at high levels. Moreover, since copper is used as a material for electric motors, it is required that a lubricating oil composition used for lubricating and cooling an electric motor has high anti-corrosion performance to copper (copper corrosion resistance).

[0007] The present invention has been made in view of the problem of the related art, and an object thereof is to provide a lubricating oil composition that is able to achieve well-balanced high insulation properties, high oxidation stability, and high extreme pressure resistance, and also that is able to achieve high copper corrosion resistance.

[Solution to Problem]

[0008] As a result of conducting earnest studies in order to achieve the above-described object, the present inventors have found that in a lubricating oil composition comprising: (A) a lubricating base oil; (B) an extreme pressure agent; and (C) a nitrogen-containing ashless dispersant, it becomes possible to allow the obtained lubricating oil composition to have well-balanced high insulation properties, high oxidation stability, and high extreme pressure resistance, and also to allow the obtained lubricating oil composition to have high copper corrosion resistance by: establishing a volume resistivity at 80°C of the lubricating oil composition to 0.0020×10^{12} Ωcm or more; establishing the component (B) to satisfy conditions of: containing (B1) a phosphorus-based extreme pressure agent, and not containing (B2) a sulfur-containing extreme pressure agent, or containing the component (B2) such that a content of sulfur derived from the component (B2) is 0.01% by mass or less based on a total amount of the lubricating oil composition; establishing the component (B1) to: (B1-1) an alkylamine salt of a phosphate ester; or a mixture of the component (B1-1) and (B1-2) at least one compound selected from the group consisting of phosphoric acid, phosphate esters, phosphite esters, and salts thereof (excluding compounds corresponding to the component (B1-1)); establishing a content of phosphorus derived from the component (B1) to 0.050% by mass or less based on the total amount of the lubricating oil composition; and establishing a mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) to 0.60 or more and 2.30 or less, and have thus completed the present invention.

[0009] That is, the present invention provides the following embodiments.

[1] A lubricating oil composition comprising:

(A) a lubricating base oil;
(B) an extreme pressure agent; and
(C) a nitrogen-containing ashless dispersant,

wherein a volume resistivity at 80°C of the lubricating oil composition is 0.0020×10^{12} Ωcm or more,
the component (B)

contains (B1) a phosphorus-based extreme pressure agent; and
does not contain (B2) a sulfur-containing extreme pressure agent, or contains the component (B2) such that a content of sulfur derived from the component (B2) is 0.01% by mass or less based on a total amount of the lubricating oil composition,

the component (B1) is

(B1-1) an alkylamine salt of a phosphate ester; or
a mixture of the component (B1-1) and (B1-2) at least one compound selected from the group consisting of phosphoric acid, phosphate esters, phosphite esters, and salts thereof (excluding compounds corresponding to the component (B1-1)),

a content of phosphorus derived from the component (B1) is 0.050% by mass or less based on the total amount of the lubricating oil composition, and
a mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) is 0.60 or more and 2.30 or less.

[2] The lubricating oil composition according to [1], wherein the lubricating base oil contains at least one selected from the group consisting of hydrorefined base oils and wax-isomerized base oils, and a kinematic viscosity at 40°C of the lubricating base oil is 20 mm^2/s or less.
[3] The lubricating oil composition according to [1] or [2], wherein a mass ratio ([sulfur]/[phosphorus]) of sulfur derived from the component (B2) and phosphorus derived from the component (B1) is 3.0 or less.
[4] The lubricating oil composition according to any one of [1] to [3], containing (D) a calcium sulfonate detergent such that a content of calcium is 200 mass ppm or less based on the total amount of the lubricating oil composition.
[5] The lubricating oil composition according to any one of [1] to [4], wherein the mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) is 0.60 or more and 1.70 or less.
[6] The lubricating oil composition according to any one of [1] to [5], wherein a ratio ($[KV40_{OL}]/[KV40_L]$) between a kinematic viscosity at 40°C ($KV40_{OL}$) of the lubricating oil composition after oxidation treatment at an oil temperature of 165°C for 192 hours by an ISOT method in accordance with JIS K2514-1 and a kinematic viscosity at 40°C ($KV40_L$)

of the lubricating oil composition before the oxidation treatment is 1.06 or less.

[7] The lubricating oil composition according to any one of [1] to [6], which is a composition for lubricating a transmission as well as for cooling and lubricating of an electric motor.

[Advantageous Effects of Invention]

[0010] The present invention makes it possible to provide a lubricating oil composition that is able to achieve well-balanced high insulation properties, high oxidation stability, and high extreme pressure resistance, and also that is able to achieve high copper corrosion resistance.

[Description of Embodiments]

[0011] Hereinafter, the present invention will be described in detail based on preferred embodiments thereof. Note that in the present specification, regarding numerical values X and Y, description "X to Y" is intended to mean "X or more and Y or less" unless otherwise noted. In such description, in the case where unit is attached to only the numerical value Y, the unit is intended to apply also to the numerical value X.

[0012] The lubricating oil composition of the present invention is a lubricating oil composition comprising:

(A) a lubricating base oil;
(B) an extreme pressure agent; and
(C) a nitrogen-containing ashless dispersant,

wherein a volume resistivity at 80°C of the lubricating oil composition is 0.0020×10^{12} Ωcm or more,

the component (B) contains (B1) a phosphorus-based extreme pressure agent; and does not contain (B2) a sulfur-containing extreme pressure agent, or contains the component (B2) such that a content of sulfur derived from the component (B2) is 0.01% by mass or less based on a total amount of the lubricating oil composition,

the component (B1) is (B1-1) an alkylamine salt of a phosphate ester; or a mixture of the component (B1-1) and (B1-2) at least one compound selected from the group consisting of phosphoric acid, phosphate esters, phosphite esters, and salts thereof (excluding compounds corresponding to the component (B1-1)),

a content of phosphorus derived from the component (B1) is 0.050% by mass or less based on the total amount of the lubricating oil composition, and

a mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) is 0.60 or more and 2.30 or less.

[Component (A): Lubricating Base Oil]

[0013] The lubricating oil composition of the present invention contains a lubricating base oil as the component (A). The lubricating base oil used as the component (A) is not particularly limited, and a known lubricating base oil (such as a mineral base oil, a synthetic base oil, or a mixed base oil of these) may be used, and for example, a lubricating base oil described in International Publication No. WO2020/095968 or the like may be used as appropriate. Note that the lubricating base oil used as the component (A) may be composed of one type of base oil or may be a mixed base oil containing two or more types of base oils.

[0014] In addition, as the lubricating base oil used as the component (A), at least one selected from Group II base oils, Group III base oils, Group IV base oils, and Group V base oils in the base oil classification by API (American Petroleum Institute) may be favorably used, and among these, Group II base oils or Group III base oils are more preferable from the viewpoint of achieving higher effects in terms of oxidation stability, corrosion resistance, and insulation properties (volume resistivity), and from the viewpoint of achieving improvement in the energy-saving performance of the electric vehicle (hereinafter, the groups in the base oil classification by API are referred to simply as "API Groups").

[0015] In addition, a mineral base oil is preferable as the lubricating base oil used as the component (A). As such a mineral base oil, a mineral base oil such as a paraffinic or naphthenic base oil, obtained by appropriately combining and applying one or two or more refining means such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrorefining, sulfuric acid washing, and clay treatment to lubricating oil fractions obtained by atmospheric distillation and vacuum distillation of crude oils can be mentioned as preferable. Moreover, among such mineral base oils, hydrorefined base oils and wax-isomerized base oils are particularly preferable as the component (A) from the viewpoint of achieving higher effects in terms of oxidation stability, corrosion resistance, and insulation properties (volume resistivity), and from the viewpoint of achieving improvement in the energy-saving performance of the electric vehicle. Note that one type of these mineral base oils may be used alone, or two or more types may be used in combination at an arbitrary ratio.

[0016] Moreover, the kinematic viscosity at 40°C of the lubricating base oil used as the component (A) (or of the mixed base oil in the case where the component (A) is a mixed base oil containing two or more types of base oils) is preferably 20 mm^2/s or less, more preferably 5 to 18 mm^2/s, and further preferably 8 to 12 mm^2/s. Establishing the kinematic viscosity at 40°C of the lubricating base oil to the above-described upper limit value or less makes it possible to achieve higher performance (effect) in terms of low-temperature viscosity properties and fuel economy as compared with the case where the kinematic viscosity is more than the above-described upper limit value. In addition, establishing the kinematic viscosity at 40°C of the lubricating base oil to the above-described lower limit value or more makes it possible to further improve oil film formation performance at lubricating portions and to further improve the extreme pressure resistance based on seizure resistance and anti-wear performance, and also to further enhance the electrical insulation properties of the fresh oil, as compared with the case where the kinematic viscosity is less than the lower limit value. Note that in the present specification, the kinematic viscosity of a base oil or a composition at 40°C or 100°C means a kinematic viscosity at each temperature (40°C or 100°C) specified in JIS K 2283-2000.

[0017] In addition, the kinematic viscosity at 100°C of the lubricating base oil used as the component (A) (or of the mixed base oil in the case where the component (A) is a mixed base oil containing two or more types of base oils) is preferably 2.0 to 4.0 mm^2/s, and more preferably 2.0 to 2.7 mm^2/s. Establishing the kinematic viscosity at 100°C of the lubricating base oil to the above-described upper limit value or less makes it possible to achieve higher performance (effect) in terms of low-temperature viscosity properties and fuel economy as compared with the case where the kinematic viscosity is more than the above-described upper limit value. In addition, establishing the kinematic viscosity at 100°C of the lubricating base oil to the above-described lower limit value or more makes it possible to further improve oil film formation performance at lubricating portions and to further improve the extreme pressure resistance based on seizure resistance and anti-wear performance, and also to further enhance the electrical insulation properties of the fresh oil, as compared with the case where the kinematic viscosity is less than the lower limit value.

[0018] In addition, the viscosity index of the lubricating base oil used as the component (A) (or of the mixed base oil in the case where the component (A) is a mixed base oil containing two or more types of base oils) is preferably 95 or more, and more preferably 120 or more. Establishing the viscosity index of the lubricating base oil to the above-described lower limit value or more makes it possible to improve viscosity-temperature properties and thermal/oxidation stability of the lubricating oil composition to further reduce the friction coefficient and also to further improve the wear resistance. Moreover, the viscosity index of the component (A) is more preferably 120 to 160 because this achieves a higher effect in terms of fuel economy. Note that in the present specification, the "viscosity index" of a base oil or a composition means a viscosity index measured in accordance with JIS K 2283-2000.

[0019] In addition, the content of sulfur of the lubricating base oil used as the component (A) (or of the mixed base oil in the case where the component (A) is a mixed base oil containing two or more types of base oils) is preferably 10 mass ppm or less (more preferably 8 mass ppm or less, further preferably 5 mass ppm or less, and particularly preferably 4 mass ppm or less). When the content of sulfur is equal to or less than the above-described upper limit, it becomes possible to further improve oxidation stability as compared with the case where the content is more than the above-described upper limit.

[0020] Moreover, although the pour point of the lubricating base oil used as the component (A) (or of the mixed base oil in the case where the component (A) is a mixed base oil containing two or more types of base oils) is not particularly limited, the pour point is preferably -12°C or less. When the pour point is equal to or less than the above-described upper limit, it becomes possible to further improve low-temperature fluidity of a lubricating oil composition ultimately obtained as compared with the case where the pour point is more than the above-described upper limit. Moreover, the pour point is more preferably -22°C or less from the viewpoint of making it possible to achieve a higher viscosity index. Note that in the present specification, the "pour point" means a pour point measured in accordance with JIS K 2269-1987.

[0021] Moreover, the flash point of the lubricating base oil used as the component (A) (or of the mixed base oil in the case where the component (A) is a mixed base oil containing two or more types of base oils) is preferably 160°C or more (further preferably 190°C or more). In addition, establishing the flash point to the above-described lower limit or more tends to further improve safety during high-temperature use as compared with the case where the flash point is less than the above-described lower limit. Note that in the present specification, the "flash point" means a flash point measured in accordance with JIS K 2265-4-2007 (Cleveland Open Cup Method).

[Component (B): Extreme Pressure Agent]

[0022] The lubricating oil composition of the present invention contains an extreme pressure agent as the component (B). The extreme pressure agent used as the component (B)

> contains (B1) a phosphorus-based extreme pressure agent; and
> does not contain (B2) a sulfur-containing extreme pressure agent, or contains the component (B2) such that a content of sulfur derived from the component (B2) is 0.01% by mass or less based on a total amount of the lubricating oil composition. That is, the extreme pressure agent as the component (B) satisfies both conditions of:

containing the component (B1); and
not containing the component (B2), or containing the component (B2) such that a content of sulfur derived from the component (B2) is 0.01% by mass or less based on the total amount of the lubricating oil composition.

[0023] As described above, the component (B) contains the component (B1) as an essential component, and by using the component (B1), even when a sulfur-containing extreme pressure agent (the component (B2)) is not used or even when the amount of the sulfur-containing extreme pressure agent (the component (B2)) used is a minute amount (such an amount that the amount of sulfur is 0.01% by mass or less based on the total amount of the lubricating oil composition), it becomes possible to exert a high load-carrying capacity and a high wear resistance, and further, it becomes possible to more efficiently establish the volume resistivity at 80°C of the lubricating oil composition to 0.0020 × 10^{12} Ωcm or more.

[0024] In addition, the phosphorus-based extreme pressure agent used as the component (B1) is

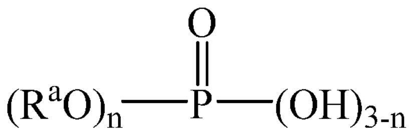
(B1-1) an alkylamine salt of a phosphate ester; or
a mixture of the component (B1-1) and (B1-2) at least one compound selected from the group consisting of phosphoric acid, phosphate esters, phosphite esters, and salts thereof (excluding compounds corresponding to the component (B1-1)). As described above, the component (B1) is one in which the component (B1-1) is used alone, or is a mixture in which the component (B1-1) and the component (B1-2) are mixed. In other words, the component (B1) is a phosphorus-based extreme pressure agent composed of at least one compound selected from the group consisting of phosphoric acid, phosphate esters, phosphite esters, and salts thereof, and contains the component (B1-1) as an essential component. Note that the "phosphorus-based extreme pressure agent" mentioned herein excludes phosphorus-based extreme pressure agents containing sulfur atoms (so-called "sulfur-phosphorus-based extreme pressure agents") (in the present specification, phosphorus-based extreme pressure agents containing sulfur atoms correspond to sulfur-containing extreme pressure agents described later).

[0025] The component (B1-1) contained as an essential component in the phosphorus-based extreme pressure agent (the component (B1)) is not particularly limited, and a known alkylamine salt of a phosphate ester usable as an extreme pressure agent may be used as appropriate. In addition, as such an alkylamine salt of a phosphate ester, a salt (a salt of a phosphate ester and the amine compound (reactant)) obtained by reacting a phosphate ester with an amine compound having an alkyl group in the molecule thereof so that a part or the whole of remaining acidic hydrogen is neutralized can be favorably used.

[0026] The phosphate ester used for forming the component (B1-1) is not particularly limited, and a known one usable as a phosphorus-based extreme pressure agent may be used as appropriate; however, the phosphate ester is preferably an acidic phosphate ester, more preferably a monoalkyl acid phosphate and/or a dialkyl acid phosphate, from the viewpoint of forming an alkylamine salt.

[0027] Examples of such monoalkyl acid phosphate and dialkyl acid phosphate include monobutyl acid phosphate, monopentyl acid phosphate, monohexyl acid phosphate, monoheptyl acid phosphate, monooctyl acid phosphate, monononyl acid phosphate, monodecyl acid phosphate, monoundecyl acid phosphate, monododecyl acid phosphate, monotridecyl acid phosphate, monotetradecyl acid phosphate, monopentadecyl acid phosphate, monohexadecyl acid phosphate, monoheptadecyl acid phosphate, monooctadecyl acid phosphate, monooleyl acid phosphate, dibutyl acid phosphate, dipentyl acid phosphate, dihexyl acid phosphate, diheptyl acid phosphate, dioctyl acid phosphate, dinonyl acid phosphate, didecyl acid phosphate, diundecyl acid phosphate, didodecyl acid phosphate, ditridecyl acid phosphate, ditetradecyl acid phosphate, dipentadecyl acid phosphate, dihexadecyl acid phosphate, diheptadecyl acid phosphate, dioctadecyl acid phosphate, dioleyl acid phosphate, and the like. Furthermore, the monoalkyl acid phosphate and dialkyl acid phosphate are preferably compounds represented by the following formula (1):

[Chem. 1]



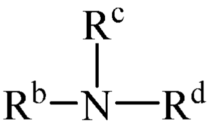
$$(R^aO)_n\text{—}\overset{\overset{\displaystyle O}{\|}}{P}\text{—}(OH)_{3-n} \qquad (1)$$

[in the formula (1), R^a represents a hydrocarbon group having 2 to 22 carbon atoms (more preferably 8 to 18 carbon atoms) (more preferably an alkyl group), and n represents an integer of 1 or 2.]. That is, as the phosphate ester used for forming the component (B1-1), it is preferable to use the compound represented by the formula (1).

[0028] In addition, as the amine compound used to form the alkylamine salt of a phosphate ester, monoalkylamine, dialkylamine, and trialkylamine can be favorably used. Examples of such amine compounds include methylamine,

ethylamine, propylamine, butylamine, pentylamine, hexylamine, heptylamine, octylamine, nonylamine, decylamine, undecylamine, dodecylamine, tridecylamine, tetradecylamine, pentadecylamine, hexadecylamine, heptadecylamine, octadecylamine, oleylamine, tetracosylamine, dimethylamine, diethylamine, dipropylamine, dibutylamine, dipentylamine, dihexylamine, diheptylamine, dioctylamine, dinonylamine, didecylamine, diundecylamine, didodecylamine, ditridecylamine, ditetradecylamine, dipentadecylamine, dihexadecylamine, diheptadecylamine, dioctadecylamine, dioleylamine, ditetracosylamine, trimethylamine, triethylamine, tripropylamine, tributylamine, tripentylamine, trihexylamine, triheptylamine, trioctylamine, trinonylamine, tridecylamine, triundecylamine, tridodecylamine, tritridecylamine, tritetradecylamine, tripentadecylamine, trihexadecylamine, triheptadecylamine, trioctadecylamine, trioleylamine, and tritetracosylamine. Such amine compounds may be used alone or in combination of two or more. The amine compound is preferably a compound represented by the following formula (2):

[Chem. 2]



$$R^b-\overset{\displaystyle R^c \atop |}{N}-R^d$$

(2)

[in the formula (2), R^b, R^c, and R^d each independently represents a hydrogen atom or a monovalent alkyl group (provided that at least one of R^b, R^c, and R^d is a monovalent alkyl group).]. Note that the monovalent alkyl group selectable as R^b, R^c, and R^d in the formula (2) may be linear or branched. The number of carbon atoms of such a monovalent alkyl group is not particularly limited, but may be 1 or more, 3 or more, 5 or more, 7 or more, 9 or more, or 11 or more, and may be 20 or less, 18 or less, 16 or less, or 14 or less. Note that the compound represented by the formula (2) is preferably a monoalkylamine (a compound in which one of R^b, R^c, and R^d in the formula (2) is a monovalent alkyl group (particularly preferably an alkyl group having 8 to 18 carbon atoms) and the others are hydrogen atoms), and/or a dialkylamine (a compound in which two of R^b, R^c, and R^d in the formula (2) are monovalent alkyl groups (particularly preferably alkyl groups having 8 to 18 carbon atoms) and the other is a hydrogen atom).

[0029] In addition, the component (B1-1) is preferably a salt of the compound represented by the formula (1) and the compound represented by the formula (2) from the viewpoint of more efficiently achieving excellent load-carrying capacity and wear resistance as well as high volume resistivity simultaneously. Moreover, one type of the component (B1-1) may be used alone, or two or more types may be used in mixture.

[0030] In addition, the component (B1-2) usable together with the component (B1-1) in the phosphorus-based extreme pressure agent (the component (B1)) is at least one compound selected from the group consisting of phosphoric acid, phosphate esters, phosphite esters, and salts thereof (excluding compounds corresponding to the component (B1-1)).

[0031] The phosphate ester usable in the component (B1-2) is not particularly limited, and a known one usable as an extreme pressure agent may be used as appropriate. Examples of such phosphate esters include the aforementioned monoalkyl acid phosphates and the aforementioned dialkyl acid phosphates, as well as tributyl phosphate, tripentyl phosphate, trihexyl phosphate, triheptyl phosphate, trioctyl phosphate, trinonyl phosphate, tridecyl phosphate, triundecyl phosphate, tridodecyl phosphate, tritridecyl phosphate, tritetradecyl phosphate, tripentadecyl phosphate, trihexadecyl phosphate, triheptadecyl phosphate, trioctadecyl phosphate, trioleyl phosphate, triphenyl phosphate, tricresyl phosphate, trixylyl phosphate, cresyl diphenyl phosphate, xylyl diphenyl phosphate, and the like.

[0032] In addition, the phosphite ester usable in the component (B1-2) is not particularly limited, and a known one usable as an extreme pressure agent may be used as appropriate, and examples thereof include dibutyl phosphite, dipentyl phosphite, dihexyl phosphite, diheptyl phosphite, dioctyl phosphite, dinonyl phosphite, didecyl phosphite, diundecyl phosphite, didodecyl phosphite, dioleyl phosphite, diphenyl phosphite, dicresyl phosphite, tributyl phosphite, tripentyl phosphite, trihexyl phosphite, triheptyl phosphite, trioctyl phosphite, trinonyl phosphite, tridecyl phosphite, triundecyl phosphite, tridodecyl phosphite, trioleyl phosphite, triphenyl phosphite, tricresyl phosphite, monolauryl hydrogen phosphite, monooleyl hydrogen phosphite, monostearyl hydrogen phosphite, monophenyl hydrogen phosphite, dibutyl hydrogen phosphite, dihexyl hydrogen phosphite, diheptyl hydrogen phosphite, di-n-octyl hydrogen phosphite, and diethylhexyl hydrogen phosphite. As such phosphite esters, dialkyl hydrogen phosphites having two alkyl groups are preferable, and dialkyl hydrogen phosphites having two alkyl groups having 4 to 12 carbon atoms are more preferable from the viewpoint of improving the seizure resistance and wear resistance.

[0033] The salts of phosphoric acid, phosphate esters, and phosphite esters usable in the component (B1-2) are not particularly limited, and known ones usable as extreme pressure agents may be used as appropriate, and among these, the following can be mentioned: salts obtained by reacting phosphoric acid, a phosphate ester, or a phosphite ester with a metal base or a nitrogen-containing compound such as ammonia or an amine compound containing only a hydrocarbon group having 1 to 8 carbon atoms or a hydrocarbon group containing a hydroxy group in the molecule thereof so that a part or the whole of remaining acidic hydrogen is neutralized.

[0034] In addition, as the component (B1), it is preferable to use a mixture of the component (B1-1) and the component (B1-2) from the viewpoint of improving seizure resistance and wear resistance. Among the component (B1-2) to be contained in such a mixture, a phosphite ester is more preferable from the viewpoint of more efficiently achieving excellent seizure resistance and wear resistance as well as excellent corrosion resistance and oxidation stability simultaneously. That is, as the component (B1), it is preferable to use a mixture of (B1-1) an alkylamine salt of a phosphate ester and a phosphite ester.

[0035] In addition, in the case where the component (B1) is a mixture of the component (B1-1) and the component (B1-2), a mass ratio of phosphorus derived from the component (B1-1) and phosphorus derived from the component (B1-2) ([P derived from the component (B1-1)]/[P derived from the component (B1-2)]) is preferably 0.4 to 2.5 (more preferably 0.4 to 2.0). When the mass ratio of phosphorus is equal to or more than the above-described lower limit, it becomes possible to achieve a higher effect in terms of seizure resistance as compared with the case where the mass ratio is less than the above-described lower limit; on the other hand, when the mass ratio is equal to or less than the above-described upper limit, it becomes possible to achieve further higher effects in terms of electrical insulation properties as compared with the case where the mass ratio is more than the above-described upper limit.

[0036] In addition, the component (B) does not contain (B2) the sulfur-containing extreme pressure agent, or contains the component (B2) such that a content of sulfur derived from the component (B2) is 0.01% by mass (100 mass ppm) or less based on the total amount of the lubricating oil composition.

[0037] Here, when the component (B) contains the sulfur-containing extreme pressure agent (the component (B2)), the sulfur-containing extreme pressure agent is not particularly limited, and a known extreme pressure agent containing sulfur may be used as appropriate. Examples of such sulfur-containing extreme pressure agents include sulfur-based extreme pressure agents such as dithiocarbamate, zinc dithiocarbamate, molybdenum dithiocarbamate (MoDTC), disulfide, polysulfide, sulfurized olefin, and sulfurized oils and fats; and sulfur-phosphorus-based extreme pressure agents such as thiophosphite esters (thiophosphites), dithiophosphite esters (dithiophosphites), trithiophosphite esters (trithiophosphites), thiophosphate esters (thiophosphates), dithiophosphate esters (dithiophosphates), trithiophosphate esters (trithiophosphates), amine salts thereof, and derivatives of these.

[0038] When the component (B) contains the sulfur-containing extreme pressure agent (the component (B2)), the content of sulfur derived from the component (B2) needs to be 0.01% by mass (100 mass ppm) or less (more preferably 80 mass ppm or less, further preferably 60 mass ppm or less, particularly preferably 50 mass ppm or less, and most preferably 20 mass ppm or less) based on the total amount of the lubricating oil composition. When the content of the component (B2) is equal to or less than the above-described upper limit, it becomes possible to achieve high oxidation stability and high copper corrosion resistance as compared with the case where the content is more than the above-described upper limit. Note that from the viewpoint of further improving the copper corrosion resistance and the insulation properties (the volume resistivity value), the component (B) preferably does not contain (B2) the sulfur-containing extreme pressure agent.

[0039] In addition, the method for producing the component (B) is not particularly limited, and a known method may be used as appropriate. Moreover, a commercially available product may be used as the component (B).

[Component (C): Nitrogen-Containing Ashless Dispersant]

[0040] The lubricating oil composition of the present invention contains a nitrogen-containing ashless dispersant (an ashless dispersant containing nitrogen) as the component (C).

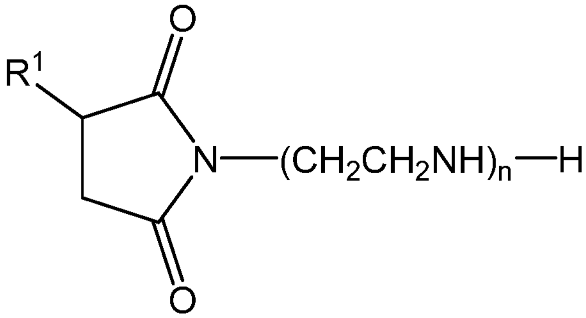
[0041] The component (C) is not particularly limited, and a known one usable as a nitrogen-containing ashless dispersant may be used as appropriate. The component (C) is more preferably an ashless dispersant having a functional group containing nitrogen as a dispersing group from the viewpoint of further improving the corrosion resistance and oxidation stability performance.

[0042] As such ashless dispersants having a functional group containing nitrogen as a dispersing group, for example, succinimides, benzylamines, polyamines, derivatives of these, or the like, each having a hydrocarbon group having 40 to 400 carbon atoms (for example, an alkyl group or an alkenyl group), can be mentioned as preferable examples.

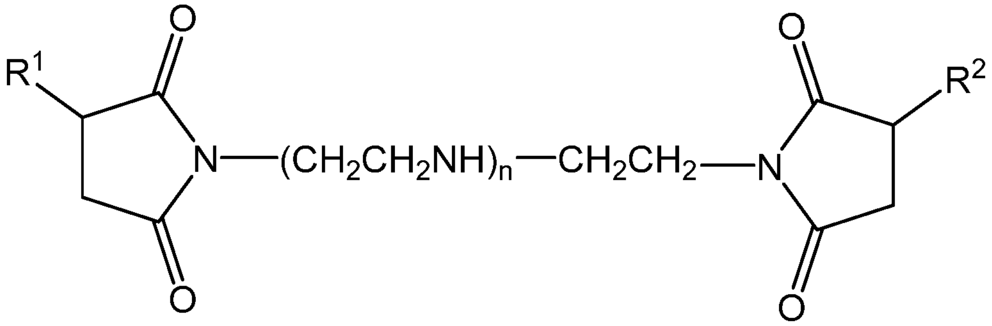
[0043] The component (C) is not particularly limited, but is more preferably at least one succinimide-based ashless dispersant selected from the group consisting of succinimides each having a hydrocarbon group having 40 to 400 carbon atoms (for example, an alkyl group or an alkenyl group) and derivatives of the succinimides (modified compounds of succinimides) from the viewpoint of further improving the corrosion resistance and oxidation stability performance.

[0044] The succinimide having a hydrocarbon group having 40 to 400 carbon atoms is not particularly limited, but is preferably a compound represented by the following formula (3) or (4):

[Chem. 3]



(3)



(4)

[in the formulae (3) and (4), R^1 and R^2 each independently represents an alkyl group having 40 to 400 carbon atoms (more preferably 60 to 350 carbon atoms) or an alkenyl group having 40 to 400 carbon atoms (more preferably 60 to 350 carbon atoms), and n represents an integer of 0 to 5.]. Note that in such formulae (3) and (4), the alkyl group or alkenyl group selectable as R^1 and the alkyl group or alkenyl group selectable as R^2 are each more preferably a branched alkyl group or alkenyl group (polyisobutenyl group) derived from an oligomer of isobutene called polyisobutylene or a polybutenyl group. Moreover, each of the alkyl group or alkenyl group selectable as R^1 and R^2 preferably has a weight-average molecular weight of 800 to 1500 (more preferably 950 to 1400). In addition, n in the formula (3) is preferably an integer of 1 to 5 (more preferably 2 to 4). On the other hand, n in the formula (4) is preferably an integer of 0 to 4 (more preferably 1 to 4, and further preferably 1 to 3). Moreover, among the compounds represented by the formulae (3) and (4), the compound represented by the formula (4) (bis type) is more preferable from the viewpoint of further improving the corrosion resistance and oxidation stability performance. Note that the method for producing such a succinimide is not particularly limited, and for example, a method may be employed for producing the above-described succinimide as a condensation reaction product by reaction of at least one selected from the group consisting of alkylsuccinic acids, alkenylsuccinic acids, each having an alkyl group or alkenyl group having 40 to 400 carbon atoms, and anhydrides thereof and a polyamine.

[0045] In addition, the derivative of the succinimide (the modified compound of the succinimide) is not particularly limited, and a known modified compound of a succinimide usable as an ashless dispersant may be used as appropriate, and examples thereof include: (i) a modified compound with an oxygen-containing organic compound (a compound obtained by reacting the succinimide with at least one selected from monocarboxylic acids having 1 to 30 carbon atoms such as fatty acids, polycarboxylic acids having 2 to 30 carbon atoms (such as oxalic acid, phthalic acid, trimellitic acid, and pyromellitic acid), anhydrides of these acids, ester compounds of these acids, alkylene oxides having 2 to 6 carbon atoms, and hydroxy(poly)oxyalkylene carbonate to neutralize or amidate a part or the whole of remaining amino groups and/or imino groups); (ii) a boron-modified compound (a compound (so-called boronated succinimide) obtained by reacting the succinimide with boric acid to neutralize or amidate a part or the whole of remaining amino groups and/or imino groups); and (iii) a phosphoric acid-modified compound (a compound obtained by reacting the succinimide with phosphoric acid to neutralize or amidate a part or the whole of remaining amino groups and/or imino groups).

[0046] In addition, among "succinimide-based ashless dispersants" suitable as the component (C), a boron-modified compound of the succinimide (boronated succinimide) is more preferable from the viewpoint of further improving the corrosion resistance and oxidation stability performance.

[0047] As the "succinimide-based ashless dispersant" suitable as the component (C), one having a nitrogen content of 1.0 to 4.8% by mass (more preferably 1.2 to 2.4% by mass) in the succinimide-based ashless dispersant is preferable. Establishing the nitrogen content within the above-described range makes it possible to more efficiently achieve high levels of corrosion resistance and oxidation stability performance. Moreover, when "boronated succinimide" is used as the succinimide-based ashless dispersant, the content of boron in the boronated succinimide is preferably 0.01 to 5.0% by mass (more preferably 0.2 to 2.2% by mass).

[0048] In addition, as the "succinimide-based ashless dispersant" suitable as the component (C), one having a weight-average molecular weight of 1000 to 9000 (more preferably 1000 to 5000) is more preferable. When the weight-average molecular weight of the succinimide-based ashless dispersant is equal to or more than the above-described lower limit value, it becomes possible to further enhance the electrical insulation properties of the fresh oil and the electrical insulation properties of the composition after oxidation degradation. In addition, when the weight-average molecular weight of the succinimide-based ashless dispersant is equal to or less than the above-described upper limit value, it becomes possible to further enhance the electrical insulation properties of the composition after oxidation degradation.

[0049] Moreover, as the "succinimide-based ashless dispersant" suitable as the component (C), one having a total base number (TBN) of 20 to 80 mg KOH/g (more preferably 30 to 60 mg KOH/g) is preferable. When the value of the total base number is within the above-described range, a further higher effect tends to be obtained in terms of oxidation stability performance.

[0050] In addition, the method for producing the component (C) is not particularly limited, and a known method may be used as appropriate. Moreover, a commercially available product may be used as the component (C).

[Regarding the Composition of the Lubricating Oil Composition]

[0051] The lubricating oil composition of the present invention contains the component (A), the component (B), and the component (C). Note that as described above, the component (B) contains the phosphorus-based extreme pressure agent, which is the component (B1), as an essential component. Moreover, as described above, the component (B1) contains the alkylamine salt of a phosphate ester, which is the component (B1-1), as an essential component.

[0052] In the lubricating oil composition of the present invention, the mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) needs to be 0.60 or more and 2.30 or less. When the mass ratio of phosphorus and nitrogen is equal to or more than the above-described lower limit, it becomes possible to simultaneously achieve high levels of both extreme pressure resistance and insulation properties by establishing the insulation properties to high levels while establishing the extreme pressure resistance to a high level as compared with the case where the mass ratio is less than the above-described lower limit; on the other hand, when the mass ratio is equal to or less than the above-described upper limit, it becomes possible to establish seizure resistance and oxidation stability both to higher levels as compared with the case where the mass ratio is more than the above-described upper limit. Moreover, the mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) is more preferably 0.60 or more and 1.70 or less (further preferably 0.60 or more and 1.50 or less, and particularly preferably 0.60 or more and 1.30 or less) because this achieves further higher effects in terms of simultaneously achieving high seizure resistance, high wear resistance, high insulation properties (volume resistivity), and excellent oxidation stability.

[0053] In addition, although the content of the component (A) in the lubricating oil composition of the present invention is not particularly limited, the content is preferably 80 to 98% by mass (more preferably 85 to 95% by mass) based on the total amount of the lubricating oil composition. When the content of the component (A) is equal to or more than the above-described lower limit, it becomes possible to achieve further excellent oxidation stability as compared with the case where the content is less than the above-described lower limit; on the other hand, when the content is equal to or less than the above-described upper limit, it becomes possible to further improve the additive effect at lubricating portions to achieve further excellent lubricity as compared with the case where the content is more than the above-described upper limit.

[0054] In addition, in the lubricating oil composition of the present invention, the content of phosphorus (P) derived from the component (B1) needs to be 0.050% by mass or less based on the total amount of the lubricating oil composition. Moreover, the content of phosphorus (P) derived from the component (B1) is preferably 190 to 410 mass ppm (further preferably 190 to 380 mass ppm) based on the total amount of the lubricating oil composition. When the content of the component (B1) is equal to or more than the above-described lower limit, it becomes possible to further improve seizure resistance and wear resistance as compared with the case where the content is less than the above-described lower limit; on the other hand, when the content is equal to or less than the above-described upper limit, it becomes possible to obtain a composition having a higher volume resistivity as compared with the case where the content is more than the above-described upper limit.

[0055] In addition, when the lubricating oil composition of the present invention contains a sulfur-containing extreme pressure agent (the component (B2)) and the component (B2) contains phosphorus, the amount of phosphorus derived from the component (B2) is preferably 100 mass ppm or less (more preferably 80 mass ppm or less) based on the total amount of the lubricating oil composition. Establishing the amount of phosphorus derived from the component (B2) to the above-described upper limit or less makes it possible to further enhance oxidation stability and corrosion resistance.

[0056] Furthermore, in the lubricating oil composition of the present invention, as described above, the lubricating oil composition satisfies the condition that: a sulfur-containing extreme pressure agent (the component (B2)) is not contained or even when a sulfur-containing extreme pressure agent (the component (B2)) is contained, the amount of sulfur derived from the component (B2) is 0.01% by mass (100 mass ppm) or less (more preferably 80 mass ppm or less, further preferably 60 mass ppm or less, particularly preferably 50 mass ppm or less, and most preferably 20 mass ppm or less) based on the total amount of the lubricating oil composition. Establishing the amount of sulfur derived from the sulfur-containing extreme pressure agent to the above-described upper limit or less makes it possible to simultaneously achieve excellent oxidation stability and excellent copper corrosion resistance.

[0057] In addition, in the lubricating oil composition of the present invention, the content of phosphorus (P) derived from the component (B1-1) is preferably 50 to 500 mass ppm (more preferably 70 to 350 mass ppm) based on the total amount of the lubricating oil composition. When the content of phosphorus is equal to or more than the above-described lower limit, it becomes possible to more easily establish load-carrying capacity (seizure resistance) and wear resistance both to higher levels as compared with the case where the content is less than the above-described lower limit; on the other hand, when the content is equal to or less than the above-described upper limit, it becomes possible to more easily establish the value of the volume resistivity to 0.0020×10^{12} Ωcm or more as compared with the case where the content is more than the above-described upper limit.

[0058] Moreover, in the lubricating oil composition of the present invention, the component (B1-2) may be used or may not be used in the component (B), and the content of phosphorus (P) derived from the component (B1-2) may be, for example, 0 to 500 mass ppm based on the total amount of the lubricating oil composition. In addition, in the case where the component (B1-2) is contained in the component (B) in the lubricating oil composition of the present invention, the content of phosphorus (P) derived from the component (B1-2) is preferably 50 to 500 mass ppm (more preferably 100 to 200 mass ppm) based on the total amount of the lubricating oil composition. When the content of phosphorus is equal to or more than the above-described lower limit, it becomes possible to further improve seizure resistance and wear resistance as compared with the case where the content is less than the above-described lower limit; on the other hand, when the content is equal to or less than the above-described upper limit, it becomes possible to more efficiently obtain a composition having a higher volume resistivity as compared with the case where the content is more than the above-described upper limit.

[0059] In addition, in the present invention, the mass ratio ([sulfur]/[phosphorus]) of sulfur derived from the component (B2) and phosphorus derived from the component (B1) is preferably 3.0 or less (more preferably 2.93 or less, and further preferably 2.2 or less). When the mass ratio of sulfur and phosphorus is equal to or less than the above-described upper limit, it becomes possible to achieve superior oxidation stability and copper corrosion resistance as compared with the case where the mass ratio is more than the above-described upper limit.

[0060] In addition, although the content of the component (C) in the lubricating oil composition of the present invention is not particularly limited, the content of the component (C) is preferably such an amount that the content of nitrogen derived from the component (C) becomes 100 to 800 mass ppm (more preferably 180 to 600 mass ppm) based on the total amount of the lubricating oil composition (note that the upper limit value of the content of nitrogen derived from the component (C) is further preferably 400 mass ppm, and particularly preferably 200 mass ppm). When the amount of nitrogen is equal to or more than the above-described lower limit, it becomes possible to further improve oxidation stability as compared with the case where the amount is less than the above-described lower limit; on the other hand, when the amount is equal to or less than the above-described upper limit, it becomes possible to more easily establish the value of the volume resistivity to 0.0020×10^{12} Ωcm or more as compared with the case where the amount is more than the above-described upper limit. Note that in the present invention, a value measured in accordance with ASTM D4951 is employed as the content of sulfur, phosphorus, nitrogen, or boron in the composition or in various components.

[0061] In addition, the lubricating oil composition of the present invention may further contain an additive besides the components (A) to (C). As such an additive, a known additive used in the field of lubricating oil compositions may be used as appropriate, and the additive is not particularly limited, but preferable examples include (D) a calcium sulfonate detergent; and an antioxidant (E).

[0062] The component (D) includes, for example, calcium sulfonates, which are calcium salts of alkyl aromatic sulfonic acids, basic salts of the calcium sulfonates, and overbased salts of the calcium sulfonates. Such alkyl aromatic sulfonic acids include, for example, so-called petroleum sulfonic acids and synthetic sulfonic acids. Examples of the petroleum sulfonic acids mentioned herein include those obtained by sulfonating alkyl aromatic compounds contained in lubricating oil fractions of mineral oil and so-called mahogany acids that are by-products generated during the production of white oil. Moreover, one example of a synthetic sulfonic acid is one obtained by sulfonating an alkyl benzene which has a linear or branched alkyl group, and which is obtained by recovering by-products generated in an alkyl benzene production plant used as a raw material for detergents or by alkylating benzene with a polyolefin. Another example of a synthetic sulfonic acid is one obtained by sulfonating an alkyl naphthalene such as dinonyl naphthalene. Moreover, the sulfonating agent for sulfonating these alkyl aromatic compounds is not particularly limited, and for example, fuming sulfuric acid or sulfuric anhydride can be used. The weight-average molecular weight of such alkyl aromatic sulfonic acids is preferably 300 to 1500, and more preferably 400 to 1300. In addition, the basic salt or overbased salt of the calcium sulfonate is not particularly limited, and a known one may be used as appropriate, and examples thereof include a calcium sulfonate (over) based with calcium carbonate, calcium borate, or the like. Note that the method for preparing the basic salt or the overbased salt is not particularly limited, and a known method may be used as appropriate (in the case where the overbased salt is a calcium sulfonate overbased with calcium carbonate, for example, a method may be employed for obtaining a calcium sulfonate overbased with calcium carbonate by reacting calcium sulfonate with a base such as calcium hydroxide in the presence of carbon dioxide).

[0063] The component (D) preferably has a total base number (TBN) of 20 to 450 mg KOH/g (more preferably 300 to 450 mg KOH/g). When the value of the total base number is within the above-described range, a further higher effect tends to be obtained in terms of oxidation stability.

[0064] In addition, in the case where the component (D) is added to the lubricating oil composition of the present invention, the content of the component (D) is preferably such an amount that the content of calcium derived from the component (D) becomes 200 mass ppm or less (more preferably 180 mass ppm or less, and further preferably 160 mass ppm or less) based on the total amount of the lubricating oil composition. When the content of calcium is equal to or less than the above-described upper limit, it becomes possible to achieve a higher effect in terms of insulation properties as compared with the case where the content is more than the above-described upper limit. Note that in the present invention, a value measured in accordance with ASTM D4951 is employed as the content of calcium in the composition or in various components.

[0065] As the component (E), a known one in the field of lubricating oil compositions (for example, a known ashless antioxidant such as an amine-based antioxidant or a phenolic antioxidant) may be used as appropriate, and the component (E) is not particularly limited, but among these, it is preferable to use (E1) a phenolic antioxidant and (E2) an amine-based antioxidant in combination.

[0066] As the component (E1), for example, a known compound as a phenolic antioxidant (for example, a compound presented as an example in International Publication No. WO2020/095970 or the like) may be used as appropriate. Such phenolic antioxidants include, for example, hindered phenol compounds and bisphenol compounds.

[0067] In addition, as the component (E2), for example, known compounds as amine-based antioxidants such as an aromatic amine-based antioxidant and a hindered amine-based antioxidant (for example, compounds presented as examples in WO 2020/095970 A) may be used as appropriate. Among the aromatic amine-based antioxidants, alkylated diphenylamines and alkylated phenyl-α-naphthylamines may be favorably used. As the hindered amine-based antioxidants, for example, compounds having 2,2,6,6-tetraalkylpiperidine skeletons (2,2,6,6-tetraalkylpiperidine derivatives) may be favorably used. Among the amine-based antioxidants, aromatic amine-based antioxidants are more preferable, and alkylated diphenylamines are particularly preferable.

[0068] In addition, when the component (E) is added to the lubricating oil composition of the present invention, the content (total amount) of the component (E) is preferably 0.01 to 4.0% by mass (more preferably 0.01 to 2.0% by mass). Moreover, when the component (E1) is added, the content of the component (E1) is preferably 0.005 to 2.0% by mass. Furthermore, when the component (E2) is added, the content of the component (E2) is preferably 0.005 to 2.0% by mass (more preferably 0.01 to 2.0% by mass). Establishing these contents within the above-described range makes it possible to improve corrosion resistance while further enhancing the oxidation prevention performance.

[0069] Although the components (D) and (E) have been described as preferable examples of additives that can be favorably used in the lubricating oil composition of the present invention, additives usable in the lubricating oil composition of the present invention are not limited to the components (D) and (E), and known other additive components may also be used as appropriate as long as the effects of the present invention are not impaired, such as a pour point depressant, a metal deactivator, a friction modifier, another dispersant other than the nitrogen-containing ashless dispersant, a viscosity index improver, a rubber swelling agent, a defoaming agent, a diluent oil, an anti-rust agent, a demulsifier, a colorant, an anti-corrosion agent, an anti-wear agent, and an acid scavenger (for example, those described in Japanese Unexamined Patent Application Publication No. 2016-3258, International Publication No. WO2015/056783, Japanese Unexamined Patent Application Publication No. 2016-160312, Japanese Unexamined Patent Application Publication No. 2003-155492, International Publication No. WO2017/073748, Japanese Unexamined Patent Application Publication No. 2020-76004, or the like).

[0070] In addition, when other additive components besides the components (D) and (E) are used, the total amount (sum amount) of the other additive components is more preferably 0.5 to 2.0% by mass based on the total amount of the lubricating oil composition. When the total amount of other additive components is equal to or more than the above-described lower limit, it becomes possible to achieve higher effects in terms of corrosion resistance and oxidation stability as compared with the case where the total amount is less than the above-described lower limit; on the other hand, when the total amount is equal to or less than the above-described upper limit, it becomes possible to achieve higher effects in terms of seizure resistance and wear resistance as compared with the case where the total amount is more than the above-described upper limit.

[0071] Note that the various additives usable in such a lubricating oil composition may be prepared separately for each component and added, or may be prepared as a mixture of other components and added. As such a mixture of other components, a commercially available package product (for example, an additive package containing a rubber swelling agent, a defoaming agent, and a pour point depressant) may be used as appropriate.

[Regarding the Properties, the Production Method, the Use, and the Like of the Lubricating Oil Composition]

[0072] The lubricating oil composition of the present invention needs to have a volume resistivity at 80°C of 0.0020×10^{12} Ωcm or more. Establishing the volume resistivity to the above-described lower limit value or more makes it possible to secure high insulation properties equal to or more than the levels required when the lubricating oil composition is used for an electric vehicle. The volume resistivity at 80°C of such a lubricating oil composition is more preferably 0.0022×10^{12} Ωcm or more, and further preferably 0.0024×10^{12} Ωcm or more, from the viewpoint of further improving the insulation properties. Note that although the upper limit value of the volume resistivity at 80°C of the lubricating oil composition is not particularly limited, the upper limit value is preferably 0.10×10^{12} Qcm from the viewpoint of discharge resistance. Such a volume resistivity employed is a value measured at an oil temperature of 80°C by conducting measurement in accordance with the volume resistivity test specified in JIS C2101.

[0073] It is preferable that in the lubricating oil composition of the present invention, a ratio ($[KV40_{OL}]/[KV40_L]$) between a kinematic viscosity at 40°C ($KV40_{OL}$) of the lubricating oil composition after oxidation treatment at an oil temperature of 165°C for 192 hours by an ISOT method in accordance with JIS K2514-1 and a kinematic viscosity at 40°C ($KV40_L$) of the lubricating oil composition before the oxidation treatment is 1.06 or less. Establishing the ratio ($[KV40_{OL}]/[KV40_L]$) between the kinematic viscosities at 40°C of the lubricating oil composition before and after the oxidation treatment to the above-described upper limit or less makes it possible to suppress an increase in viscosity owing to oxidation degradation as compared with the case where the ratio is more than the above-described upper limit, and to exert high transmission efficiency over a longer period of time when the lubricating oil composition is used for a transmission. The ratio ($[KV40_{OL}]/[KV40_L]$) between the kinematic viscosities at 40°C of the lubricating oil composition before and after the oxidation treatment is more preferably 0.95 or more and 1.06 or less, and further preferably 1.0 or more and 1.02 or less. Establishing the ratio ($[KV40_{OL}]/[KV40_L]$) within the above-described range tends to achieve a higher effect in terms of oxidation stability, and to exert high transmission efficiency over a longer period of time when the lubricating oil composition is used for a transmission, as compared with the case where the ratio is out of the above-described range.

[0074] The lubricating oil composition of the present invention is preferably one having a kinematic viscosity at 40°C ($KV40_L$: the kinematic viscosity of a composition to which the aforementioned oxidation treatment is not conducted (fresh oil)) of 8.0 to 18.0 mm^2/s (more preferably 8.0 to 14.0 mm^2/s). When the kinematic viscosity at 40°C of the lubricating oil composition is equal to or less than the above-described upper limit, it becomes possible to further reduce the stirring resistance in a relatively low temperature range around 40°C (preferably around 20 to 60°C) as compared with the case where the kinematic viscosity is more than the above-described upper limit, and to further improve the power transmission efficiency even in a low-temperature state, for example immediately after the start of use, so that it becomes possible to further improve the fuel economy. In addition, when the kinematic viscosity at 40°C of the lubricating oil composition is equal to or more than the above-described lower limit value, oil film formation and oil film retention of the lubricating oil composition at lubricating portions are further improved in a relatively low temperature range around 40°C (preferably around 20 to 60°C), making it possible to maintain a more favorable lubrication state, and from this viewpoint, it becomes possible to further improve the gear transmission efficiency and the energy efficiency.

[0075] The lubricating oil composition of the present invention is preferably one having a kinematic viscosity at 40°C ($KV40_{OL}$) of 8.0 to 20.0 mm^2/s (more preferably 8.0 to 18.0 mm^2/s) for the lubricating oil composition after oxidation treatment at an oil temperature of 165°C for 192 hours by an ISOT method in accordance with JIS K2514-1. When $KV40_{OL}$ of the lubricating oil composition is equal to or less than the above-described upper limit, it becomes possible to achieve higher effects in terms of improvement in the oxidation stability and improvement in the transmission efficiency when the lubricating oil composition is used for a transmission as compared with the case where $KV40_{OL}$ is more than the above-described upper limit; on the other hand, when $KV40_{OL}$ of the lubricating oil composition is equal to or more than the above-described lower limit, it becomes possible to achieve higher wear resistance and seizure resistance as compared with the case where $KV40_{OL}$ is less than the above-described lower limit.

[0076] The lubricating oil composition of the present invention is preferably one having a kinematic viscosity at 100°C of 1.8 to 4.0 mm^2/s (more preferably 2.2 to 3.5 mm^2/s). When the kinematic viscosity at 100°C of the lubricating oil composition is equal to or less than the above-described upper limit, it becomes possible to further reduce the viscosity and the stirring resistance in a relatively high temperature range around 100°C as compared with the case where the kinematic viscosity is more than the above-described upper limit, so that it becomes possible to further improve the power transmission efficiency, and to improve the fuel economy. In addition, when the kinematic viscosity at 100°C of the lubricating oil composition is equal to or more than the above-described lower limit, oil film formation and oil film retention of the lubricating oil composition at lubricating portions are further improved in a relatively high temperature range around 100°C (preferably around 80 to 120°C), making it possible to more uniformly maintain the oil film, so that it becomes possible to establish the seizure resistance during use to a higher level.

[0077] In addition, the lubricating oil composition of the present invention is preferably one having a viscosity index of 105 or more (more preferably 120 or more). When the viscosity index is equal to or more than the above-described lower limit (more preferably 120 or more), it becomes possible to further improve the viscosity-temperature properties and anti-wear performance of the lubricating oil composition and also to further improve the fuel economy, as compared with the case where the viscosity index is less than the above-described lower limit.

[0078] The method for producing the lubricating oil composition of the present invention is not particularly limited, and the lubricating oil composition may be prepared by selecting and mixing each component to be contained as appropriate such that the lubricating oil composition of the present invention can be obtained (such that the above-described conditions are satisfied).

[0079] Since the lubricating oil composition of the present invention has well-balanced high insulation properties, high oxidation stability, and high extreme pressure resistance, and also has high copper corrosion resistance, the use thereof is not particularly limited, but the lubricating oil composition can be favorably used as a composition for lubricating a transmission as well as for cooling and lubricating of an electric motor. That is, the lubricating oil composition of the present invention can be favorably used as a lubricating oil composition for electric vehicles provided with electric motors and transmissions.

[Examples]

[0080] Hereinafter, the present invention will be described in more detail based on Examples and Comparative Examples; however, the present invention is not limited to Examples given below.

(Regarding Components Used in Each Example and the Like)

[0081] First, base oils and additives used in each Example and the like will be presented below.

[(A) Lubricating Base Oil]

(A1) a wax-isomerized base oil [mineral oil: API Group III, kinematic viscosity at 40°C: 9.422 mm^2/s, kinematic viscosity at 100°C: 2.676 mm^2/s, viscosity index: 125, content of sulfur in the base oil (sulfur content of the base oil): 0 mass ppm, pour point: - 37°C, flash point: 190°C]; and
(A2) a hydrocracked base oil [mineral oil: API Group II, kinematic viscosity at 40°C: 8.546 mm^2/s, kinematic viscosity at 100°C: 2.431 mm^2/s, viscosity index: 105, content of sulfur in the base oil (sulfur content of the base oil): 0 mass ppm, pour point: - 30°C, flash point: 170°C].

[(B) Extreme Pressure Agent]

<(B1) Phosphorus-Based Extreme Pressure Agent>

(B1-1) an alkylamine salt of a phosphate ester [a salt of a phosphate ester (a mixture of a monoester and a diester: a compound represented by the above-described formula (1) in which R^a in the formula is an oleyl group (a group represented by the formula: $C_{18}H_{35}$)) and an alkylamine (a compound represented by the above-described formula (2) in which one of R^b, R^c, and R^d in the formula is a dodecyl group (a group represented by the formula: $C_{12}H_{25}$) and the others of R^b, R^c, and R^d are hydrogen atoms)];
(B1-2) a phosphite ester [dibutyl hydrogen phosphite]; and

<(B2) Sulfur-Containing Extreme Pressure Agent>
(B2-1) a thiophosphate ester [phosphorus content: 100000 ppm, sulfur content: 190000 mass ppm].

[(C) Nitrogen-Containing Ashless Dispersant]
(C1) a succinimide-based ashless dispersant [boronated succinimide, nitrogen content: 2.0% by mass, boron content: 0.5% by mass, total base number (TBN): 50, succinimide type: bis type (a boron-modified compound of a bis type succinimide represented by the above-described formula (4) (here, R^1 and R^2 in the formula (4) are polyisobutenyl groups each having a weight-average molecular weight (Mw) of 1000 and n is 3))].
[(D) Calcium Sulfonate Detergent]
(D1) a calcium sulfonate detergent [total base number (TBN): 400 mg KOH/g, content of calcium atoms: 15.0% by mass].
[(E) Antioxidant]

(E1) a phenolic antioxidant [3-(4-hydroxy-3,5-diisopropylphenyl)propionic acid octyl]; and
(E2) an amine-based antioxidant [alkylated diphenylamine].

[(F) Other Additives]
(F1) a performance additive [a mixture of a rubber swelling agent, a defoaming agent, and a pour point depressant (additive package)].

(Examples 1 to 7 and Comparative Examples 1 to 6)

[0082] Lubricating oil compositions of Examples 1 to 7 and Comparative Examples 1 to 6 were prepared by using the aforementioned components to obtain compositions shown in Tables 1 and 2. Note that in the item "Composition" in Tables 1 and 2, "-" indicates that the corresponding component was not used. In addition, in the item "Composition" in Tables 1 and 2, "inmass%" represents the content based on mass relative to the total amount of the lubricating base oil (% by mass), "mass%" represents the content based on mass relative to the total amount of the lubricating oil composition (% by mass), "ppm (in terms of N)" represents the content based on mass in terms of nitrogen atoms relative to the total amount of the lubricating oil composition (mass ppm: the content of nitrogen derived from the component relative to the total amount of the lubricating oil composition), "ppm (in terms of P)" represents the content based on mass in terms of phosphorus atoms relative to the total amount of the lubricating oil composition (mass ppm: the content of phosphorus derived from the component relative to the total amount of the lubricating oil composition), "ppm (in terms of S)" represents the content based on mass in terms of sulfur atoms relative to the total amount of the lubricating oil composition (mass ppm: the content of sulfur derived from the component relative to the total amount of the lubricating oil composition), and "ppm (in terms of Ca)" represents the content based on mass in terms of calcium atoms relative to the total amount of the lubricating oil composition (mass ppm: the content of calcium derived from the component relative to the total amount of the lubricating oil composition). Moreover, the contents of phosphorus, nitrogen, sulfur, and calcium in the composition are values measured in accordance with ASTM D4951. In addition, in Tables 1 and 2, the description "Phosphorus Content Derived from Component (B1)" indicates the proportion (% by mass: mass%) of the content based on mass of phosphorus derived from the component (B1) contained in the lubricating oil composition, the description "Sulfur Content Derived from Component (B2)" indicates the proportion (% by mass: mass%) of the content based on mass of sulfur derived from the component (B2) contained in the lubricating oil composition, and the description "Nitrogen Content Derived from Component (C)" indicates the proportion (% by mass: mass%) of the content based on mass of nitrogen derived from the component (C) contained in the lubricating oil composition. Moreover, in Tables 1 and 2, the description "Phosphorus Derived from Component (B1)/Nitrogen Derived from Component (C)" indicates a ratio (mass ratio: [phosphorus]/[nitrogen]) between the "Phosphorus Content Derived from Component (B1)" and the "Nitrogen Content Derived from Component (C)," and the description "Sulfur Derived from Component (B2)/Phosphorus Derived from Component (B1)" indicates a ratio (mass ratio: [sulfur]/[phosphorus]) between the "Sulfur Content Derived from Component (B2)" and the "Phosphorus Content Derived from Component (B1)."

[Regarding Evaluation Methods on the Properties of the Lubricating Oil Composition Obtained in Each Example and the Like]

<Measurement of Volume Resistivity>

[0083] The volume resistivity of fresh oil of each lubricating oil composition was measured. Here, the measurement of the volume resistivity was conducted at an oil temperature of 80°C in accordance with the volume resistivity test specified in JIS C2101. The results thus obtained are shown in Tables 1 and 2. When the volume resistivity at 80°C is 0.0020×10^{12} $\Omega\cdot$cm or more, it can be evaluated that the lubricating oil composition has high insulation properties.

<Falex Seizure Test: Confirmation Test on Seizure Resistance>

[0084] For each lubricating oil composition, the Falex seizure test was conducted in accordance with ASTM D3233 Method A, and the load (unit: lbf) at which seizure occurred was measured. The results thus obtained are shown in Tables 1 and 2. Note that when the load at which seizure occurred is 700 lbf or more, it can be determined that seizure resistance is good.

<Falex Wear Test: Confirmation Test on Wear Resistance>

[0085] For each lubricating oil composition, the Falex test (the Falex wear resistance test) was conducted at an oil temperature of 80°C, a load of 390 lb, a rotational speed of 290 rpm, and for 1 hour in accordance with ASTM D2670, and the amount of wear (mg) was measured. The results thus obtained are shown in Tables 1 and 2. When the amount of wear is 55.0 mg or less, it can be determined that the wear resistance is good.

<Confirmation Test on Copper Strip Corrosion Resistance>

[0086] Approximately 30 mL of a sample was prepared from each lubricating oil composition, and the copper strip corrosion test was conducted in accordance with JIS K 2513 to evaluate copper strip corrosion resistance. That is, in accordance with JIS K2513, a copper strip was completely immersed in approximately 30 mL of the sample, the temperature was maintained at an oil temperature of 150°C for 192 hours, the copper strip was then taken out, and washed; the corrosiveness of the sample to copper was determined by comparison with a copper corrosion standard to evaluate the copper corrosion resistance. The results thus obtained are shown in Tables 1 and 2. Note that when a determination value (discoloration number) of the copper strip corrosion standard is 2 or less, it can be determined that the copper corrosion resistance is high.

<Evaluation of Oxidation Stability: Confirmation Test on the Presence or Absence of the Generation of Strong Acid Number After Oxidation Treatment>

[0087] For each lubricating oil composition, after oxidation treatment at an oil temperature of 165°C for 192 hours by the ISOT (Indiana Stirring Oxidation Test) method in accordance with JIS K2514-1, the presence or absence of generation of a strong acid number was verified by using the lubricating oil composition after the oxidation treatment. The lubricating oil compositions without generation of a strong acid number were evaluated as "Pass" as compositions having high oxidation stability, and the lubricating oil compositions with generation of a strong acid number were evaluated as "Fail" as compositions having insufficient oxidation stability. The results thus obtained are shown in Tables 1 and 2.

<Measurement of the Ratio of Kinematic Viscosity>

[0088] For each lubricating oil composition, the kinematic viscosity at 40°C ($KV40_{OL}$) of the lubricating oil composition after oxidation treatment at an oil temperature of 165°C for 192 hours by an ISOT method in accordance with JIS K2514-1 and the kinematic viscosity at 40°C ($KV40_{L}$) of the lubricating oil composition before the oxidation treatment were determined, and a ratio ($[KV40_{OL}]/[KV40_{L}]$) thereof was determined. Note that a value obtained in accordance with the specification in JIS K 2283-2000 was employed as the kinematic viscosity at 40°C. The results thus obtained are shown in Tables 1 and 2.

[Table 1]

						Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7
Composition	(A) Lubricating Base Oil	Wax-Isomerized Base Oil		(A1)	inmass%	100	-	100	100	100	100	100
		Hydrocracked Base Oil		(A2)	inmass%	-	100	-	-	-	-	-
	(B) Extreme Pressure Agent	(B1) Phosphorus-Based Extreme Pressure Agent	Alkylamine Salt of Phosphate Ester	(B1-1)	ppm (in terms of P)	90	90	90	300	70	90	90
			Phosphite Ester	(B1-2)	ppm (in terms of P)	130	130	130	130	130	130	130
		(B2) Sulfur-Containing Extreme Pressure Agent	Thiophosphate Ester	(B2-1)	ppm (in terms of S)	-	-	20	-	-	-	-
	(C) Ashless Dispersant	Boronated Succinimide		(C1)	ppm (in terms of N)	294	294	294	294	294	180	340
	(D) Detergent	Calcium Sulfonate Detergent		(D1)	ppm (in terms of Ca)	130	130	130	130	130	130	130
	(E) Antioxidant	Phenolic Antioxidant		(E1)	mass%	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		Amine-Based Antioxidant		(E2)	mass%	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	(F) Performance Additive	Mixture of Rubber Swelling Agent, Defoaming Agent, and Pour Point Depressant		(F1)	mass%	1	1	1	1	1	1	1
	Sum Amount of Components (B), (C), (D), (E), and (F) (Based on Total Amount of Composition)				mass%	3.69	3.69	3.71	4.55	3.61	3.12	5.00

(continued)

			Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7
Content Ratios of Phosphorus, Nitrogen, etc.	Content of Phosphorus Derived from Component (B1) (Based on Total Amount of Composition)	mass%	0.022	0.022	0.022	0.043	0.020	0.022	0.022
	Content of Sulfur Derived from Component (B2) (Based on Total Amount of Composition)	mass%	0	0	0.002	0	0	0	0
	Content of Nitrogen Derived from Component (C) (Based on Total Amount of Composition)	mass%	0.0294	0.0294	0.0294	0.0294	0.0294	0.0180	0.0340
	Phosphorus Derived from Component (B1) / Nitrogen Derived from Component (C) [Mass Ratio: P/N]	Mass Ratio	0.75	0.75	0.75	1.46	0.68	1.22	0.65
	Sulfur Derived from Component (B2) / Phosphorus Derived from Component (B1) [Mass Ratio: S/P]	Mass Ratio	0.00	0.00	0.09	0.00	0.00	0.00	0.00
Physical Properties of Lubricating Base Oil	Kinematic Viscosity at 40°C	mm^2/s	9.422	8.546	9.422	9.422	9.422	9.422	9.422
	Kinematic Viscosity at 100°C	mm^2/s	2.676	2.431	2.676	2.676	2.676	2.676	2.676
	Viscosity Index of Lubricating Base Oil	-	125	105	125	125	125	125	125
Physical Properties of Lubricating Oil Composition	Kinematic Viscosity at 40°C	mass%	9.60	8.60	9.63	10.10	9.64	9.50	10.32
	Kinematic Viscosity at 100°C	mass%	2.70	2.40	2.71	2.78	2.71	2.69	2.83
	Viscosity Index of Lubricating Oil Composition	-	129	105	124	121	123	125	123

(continued)

			Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7
Evaluation Results	Measurement Test for Volume Resistivity (In Accordance With JIS C2101: Oil Temperature of 80°C)	Volume Resistivity ($\times 10^{12}$ Ω·cm)	0.0030	0.0030	0.0021	0.0024	0.0032	0.0038	0.0026
	Falex Seizure Test (In Accordance With ASTM D3233 Method A)	Seizure Load (lbf)	1170	1130	1240	1200	1100	750	1150
	Falex Wear Test (In Accordance With ASTM D2670)	Amount of Wear (mg)	22.8	24.3	22.4	20.1	26.7	35.2	25.3
	Copper Strip Corrosion Test (In Accordance With JIS K2513)	Copper Corrosion Standard (Discoloration Number)	1a	1a	2a	1a	1a	1a	1a
	Oxidation Stability Test (Verification of Presence or Absence of Generation of Strong Acid Number After ISOT Test)	Without Generation of Strong Acid Number: Pass With Generation of Strong Acid Number: Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass
	Ratio of Kinematic Viscosities at 40°C Between Lubricating Oil Compositions Before and After Oxidation Treatment ($KV40_{OL}/KV40_{L}$)		1.02	1.01	1.02	1.05	1.02	1.02	1.02

[Table 2]

						Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Composition	(A) Lubricating Base Oil	Wax-Isomerized Base Oil		(A1)	inmass%	100	100	100	100	100	100
		Hydrocracked Base Oil		(A2)	inmass%	-	-	-	-	-	-
	(B) Extreme Pressure Agent	(B1) Phosphorus-Based Extreme Pressure Agent	Alkylamine Salt of Phosphate Ester	(B1-1)	ppm (in terms of P)	400	90	90	50	90	-
			Phosphite Ester	(B1-2)	ppm (in terms of P)	130	130	130	50	130	210
		(B2) Sulfur-Containing Extreme Pressure Agent	Thiophosphate Ester	(B2-1)	ppm (in terms of S)	-	-	-	-	200	-
	(C) Ashless Dispersant	Boronated Succinimide		(C1)	ppm (in terms of N)	294	82	612	294	294	294
	(D) Detergent	Calcium Sulfonate Detergent		(D1)	ppm (in terms of Ca)	130	130	130	130	130	130
	(E) Antioxidant	Phenolic Antioxidant		(E1)	mass%	*0.4*	0.4	0.4	0.4	0.4	0.4
		Amine-Based Antioxidant		(E2)	mass%	0.4	0.4	0.4	0.4	0.4	0.4
	(F) Performance Additive	Mixture of Rubber Swelling Agent, Defoaming Agent, and Pour Point Depressant		(F1)	mass%	1	1	1	1	1	1
	Sum Amount of Components (B), (C), (D), (E), and (F) (Based on Total Amount of Composition)				mass%	4.94	2.63	5.32	3.52	3.93	3.85

(continued)

			Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Content Ratios of Phosphorus, Nitrogen, etc.	Content of Phosphorus Derived from Component (B1) (Based on Total Amount of Composition)	mass%	0.053	0.022	0.022	0.010	0.022	0.022
	Content of Sulfur Derived from Component (B2) (Based on Total Amount of Composition)	mass%	0	0	0	0	0.02	0
	Content of Nitrogen Derived from Component (C) (Based on Total Amount of Composition)	mass%	0.0294	0.0082	0.0612	0.0294	0.0294	0.0294
	Phosphorus Derived from Component (B1) / Nitrogen Derived from Component (C) [Mass Ratio: P/N]	Mass Ratio	1.80	2.68	0.36	0.34	0.75	0.75
	Sulfur Derived from Component (B2) / Phosphorus Derived from Component (B1) [Mass Ratio: S/P]	Mass Ratio	0.00	0.00	0.00	0.00	4.55	0.00
Physical Properties of Lubricating Base Oil	Kinematic Viscosity at 40°C	mm^2/s	9.422	9.422	9.422	9.422	9.422	9.422
	Kinematic Viscosity at 100°C	mm^2/s	2.676	2.676	2.676	2.676	2.676	2.676
	Viscosity Index of Lubricating Base Oil	-	125	125	125	125	125	125
Physical Properties of Lubricating Oil Composition	Kinematic Viscosity at 40°C	mass%	10.22	9.49	10.50	9.49	9.96	9.60
	Kinematic Viscosity at 100°C	mass%	2.81	2.68	2.86	2.68	2.76	2.70
	Viscosity Index of Lubricating Oil Composition	-	122	123	123	123	122	129

(continued)

			Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Evaluation Results	Measurement Test for Volume Resistivity (In Accordance With JIS C2101: Oil Temperature of 80°C)	Volume Resistivity ($\times 10^{12}$ Ω·cm)	0.0018	0.0040	0.0010	0.0035	0.0030	0.0015
	Falex Seizure Test (In Accordance With ASTM D3233 Method A)	Seizure Load (lbf)	1240	670	1100	500	1170	1170
	Falex Wear Test (In Accordance With ASTM D2670)	Amount of Wear (mg)	20.1	25.3	23.1	59.5	22.8	22.8
	Copper Strip Corrosion Test (In Accordance With JIS K2513)	Copper Corrosion Standard (Discoloration Number)	1a	1a	1a	1a	3b	1a
	Oxidation Stability Test (Verification of Presence or Absence of Generation of Strong Acid Number After ISOT Test)	Without Generation of Strong Acid Number: Pass With Generation of Strong Acid Number: Fail	Pass	Fail	Pass	Pass	**Fail**	Pass
	Ratio of Kinematic Viscosities at 40°C Between Lubricating Oil Compositions Before and After Oxidation Treatment ($KV40_{OL}/KV40_{L}$)		(Unmeasured)	1.10	1.02	1.02	1.08	(Unmeasured)

[0089] As is clear from the results shown in Table 1, it was found that the lubricating oil compositions obtained in Examples 1 to 7 (corresponding to the lubricating oil compositions of the present invention) had a volume resistivity of 0.0020 × 10^{12} Ωcm or more and were suitable for lubricating and cooling electric motors for which high levels of insulation properties are required. Moreover, it was confirmed that the lubricating oil compositions obtained in Examples 1 to 7 (corresponding to the lubricating oil compositions of the present invention) had good seizure resistance and good wear resistance, and also had high extreme pressure resistance based on seizure resistance and wear resistance. Furthermore, it was found that in the lubricating oil compositions obtained in Examples 1 to 7 (corresponding to the lubricating oil compositions of the present invention), a strong acid number did not generate and oxidation stability was also high. Moreover, as shown in Table 1, it was also confirmed that the lubricating oil compositions obtained in Examples 1 to 7 (corresponding to the lubricating oil compositions of the present invention) had high copper corrosion resistance. In addition, in all of the lubricating oil compositions obtained in Examples 1 to 7 (corresponding to the lubricating oil compositions of the present invention), the ratio ($[KV40_{OL}]/[KV40_{L}]$) between the kinematic viscosities at 40°C of the lubricating oil compositions before and after the oxidation treatment was 1.05 or less, and from this viewpoint as well, it was found that the lubricating oil compositions had high oxidation stability. It was found from these results that the lubricating oil compositions obtained in Examples 1 to 7 had insulation properties, oxidation stability, and extreme pressure resistance, all of which were at a high level, and had these properties in a well-balanced manner and also had high copper corrosion resistance.

[0090] In contrast, as is clear from the results shown in Table 2, in the lubricating oil composition obtained in Comparative Example 1 in which the content of phosphorus derived from the component (B1) was a value exceeding 0.050% by mass (0.053% by mass) based on the total amount of the lubricating oil composition, the volume resistivity was less than 0.0020 × 10^{12} Ωcm, and the insulation properties could not be established to high levels. Moreover, the lubricating oil composition obtained in Comparative Example 2 in which the mass ratio (P/N) between the content of phosphorus derived from the component (B1) and the content of nitrogen derived from the component (C) was a value exceeding 2.30 (2.68) did not have sufficient seizure resistance, and the extreme pressure resistance could not be established to a high level. In addition, in the lubricating oil composition obtained in Comparative Example 2, a strong acid number generated, and oxidation stability could not be established to a high level. Furthermore, the lubricating oil compositions obtained in Comparative Examples 3 and 4 in which the mass ratio (P/N) between the content of phosphorus derived from the component (B1) and the content of nitrogen derived from the component (C) was less than 0.60 were not necessarily sufficient in terms of extreme pressure resistance or insulation properties. Moreover, in the lubricating oil composition obtained in Comparative Example 5 containing a sulfur-containing extreme pressure agent in such an amount that the amount of sulfur was 200 ppm, a strong acid number generated, and oxidation stability could not be established to a high level. Furthermore, the lubricating oil composition obtained in Comparative Example 6 in which the alkylamine salt of a phosphate ester was not used had a volume resistivity of less than 0.0020 × 10^{12} Qcm, and the insulation properties could not be established to high levels.

[Industrial Applicability]

[0091] As described above, the present invention makes it possible to provide a lubricating oil composition that is able to achieve well-balanced high insulation properties, high oxidation stability, and high extreme pressure resistance, and also that is able to achieve high copper corrosion resistance. Therefore, the lubricating oil composition of the present invention is particularly useful as a lubricating oil composition for electric vehicles.

Claims

1. A lubricating oil composition comprising:

(A) a lubricating base oil;
(B) an extreme pressure agent; and
(C) a nitrogen-containing ashless dispersant,
wherein a volume resistivity at 80°C of the lubricating oil composition is 0.0020 × 10^{12} Qcm or more,
the component (B)

contains (B1) a phosphorus-based extreme pressure agent; and
does not contain (B2) a sulfur-containing extreme pressure agent, or contains the component (B2) such that a content of sulfur derived from the component (B2) is 0.01% by mass or less based on a total amount of the lubricating oil composition,

the component (B1) is

(B1-1) an alkylamine salt of a phosphate ester; or
a mixture of the component (B1-1) and (B1-2) at least one compound selected from the group consisting of phosphoric acid, phosphate esters, phosphite esters, and salts thereof (excluding compounds corresponding to the component (B1-1)),

a content of phosphorus derived from the component (B1) is 0.050% by mass or less based on the total amount of the lubricating oil composition, and
a mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) is 0.60 or more and 2.30 or less.

2. The lubricating oil composition according to claim 1, wherein the lubricating base oil contains at least one selected from the group consisting of hydrorefined base oils and wax-isomerized base oils, and a kinematic viscosity at 40°C of the lubricating base oil is 20 mm^2/s or less.

3. The lubricating oil composition according to claim 1, wherein a mass ratio ([sulfur]/[phosphorus]) of sulfur derived from the component (B2) and phosphorus derived from the component (B1) is 3.0 or less.

4. The lubricating oil composition according to claim 1, containing (D) a calcium sulfonate detergent such that a content of calcium is 200 mass ppm or less based on the total amount of the lubricating oil composition.

5. The lubricating oil composition according to claim 1, wherein the mass ratio ([phosphorus]/[nitrogen]) of phosphorus derived from the component (B1) and nitrogen derived from the component (C) is 0.60 or more and 1.70 or less.

6. The lubricating oil composition according to claim 1, wherein a ratio ($[KV40_{OL}]/[KV40_L]$) between a kinematic viscosity at 40°C ($KV40_{OL}$) of the lubricating oil composition after oxidation treatment at an oil temperature of 165°C for 192 hours by an ISOT method in accordance with JIS K2514-1 and a kinematic viscosity at 40°C ($KV40_L$) of the lubricating oil composition before the oxidation treatment is 1.06 or less.

7. The lubricating oil composition according to claim 1, which is a composition for lubricating a transmission as well as for cooling and lubricating of an electric motor.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/026182

A. CLASSIFICATION OF SUBJECT MATTER

C10M 169/04(2006.01)i; ***C10M 101/02***(2006.01)i; ***C10M 133/56***(2006.01)i; ***C10M 135/10***(2006.01)i; ***C10M 137/08***(2006.01)i; *C10N 10/04*(2006.01)n; *C10N 30/00*(2006.01)n; *C10N 30/06*(2006.01)n; *C10N 30/08*(2006.01)n; *C10N 30/10*(2006.01)n; *C10N 30/12*(2006.01)n; *C10N 40/00*(2006.01)n; *C10N 40/02*(2006.01)n; *C10N 40/04*(2006.01)n; *C10N 40/06*(2006.01)n

FI: C10M169/04; C10M101/02; C10M133/56; C10M135/10; C10M137/08; C10N10:04; C10N30:00 Z; C10N30:06; C10N30:08; C10N30:10; C10N30:12; C10N40:00 D; C10N40:02; C10N40:04; C10N40:06

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)

C10M169/04; C10M101/02; C10M133/56; C10M135/10; C10M137/08; C10N10/04; C10N30/00; C10N30/06; C10N30/08; C10N30/10; C10N30/12; C10N40/00; C10N40/02; C10N40/04; C10N40/06

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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 Y	JP 2021-155740 A (EMG LUBRICANTS GK) 07 October 2021 (2021-10-07) claims, paragraph [0026], example 10	1-7 2, 4
Y	JP 2021-6617 A (ENEOS CORP) 21 January 2021 (2021-01-21) paragraph [0113]	2
Y	JP 2013-199594 A (JX NIPPON OIL & ENERGY CORP) 03 October 2013 (2013-10-03) paragraph [0047]	4
A	JP 2019-157131 A (AFTON CHEMICAL CORPORATION) 19 September 2019 (2019-09-19) paragraphs [0312], [0175], [0177], example 4	1-7
A	JP 2004-210988 A (ASAHI DENKA KOGYO KK) 29 July 2004 (2004-07-29) examples 3, 8, 11	1-7

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

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier application or patent but published on or after the international filing date
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"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search **06 September 2023**	Date of mailing of the international search report **19 September 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/026182

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2014-19788 A (TONENGENERAL SEKIYU KK) 03 February 2014 (2014-02-03) claims, examples	1-7
A	JP 2016-108406 A (TONENGENERAL SEKIYU KK) 20 June 2016 (2016-06-20) claims, examples	1-7
A	JP 2015-178632 A (JX NIPPON OIL & ENERGY CORP) 08 October 2015 (2015-10-08) claims, examples	1-7

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/026182

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JP 2021-155740 A	07 October 2021	US 2020/0071634 A1 claims, paragraph [0045], example 10 WO 2018/078434 A1 EP 3533857 A1	
JP 2021-6617 A	21 January 2021	US 2020/0407660 A1 paragraph [0134] CN 112143543 A	
JP 2013-199594 A	03 October 2013	US 2015/0045271 A1 paragraph [0061] WO 2013/145037 A1 EP 2832831 A1 CN 104321416 A	
JP 2019-157131 A	19 September 2019	US 2019/0284496 A1 example 4, etc. EP 3546550 A1 CN 110272775 A	
JP 2004-210988 A	29 July 2004	(Family: none)	
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JP 2016-108406 A	20 June 2016	(Family: none)	
JP 2015-178632 A	08 October 2015	(Family: none)	

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- JP 2020076004 A **[0069]**