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(54) LUBRICATING OIL COMPOSITION, METHOD FOR USING SAME, AND METHOD FOR PRODUCING SAME

(57) Provided is a lubricating oil composition, including: a vegetable oil (A); a zinc dithiophosphate (B); and an amine-based antioxidant (C), wherein a total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to a total amount of the constituent fatty acids in the vegetable oil (A), wherein a content of the amine-based antioxidant (C) is 2.00 mass% or more with respect to a total amount of the lubricating oil composition, and wherein when the lubricating oil composition further includes a phosphorus-free phenol-based antioxidant (D), a content of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

EP 4 549 536 A1

Description

Technical Field

[0001] The present invention relates to a lubricating oil composition, and a method of using the composition and a method of producing the composition.

Background Art

[0002] In recent years, along with the introduction of the concept of carbon neutrality, the utilization of a plant-derived raw material has started to progress. In the field of a lubricating oil, an investigation has been made on the use of a vegetable oil as a base oil.

[0003] In, for example, Patent Literature 1, as an animal and vegetable lubricating oil having a low-melting point property, a high viscosity, and high stability, there is a proposal of the following animal and vegetable lubricating oil: the content of an isolated trans-isomer in constituent fatty acids of a triglyceride is 40 mass% or more, and the oil has an iodine value of from 50 to 90.

Citation List

Patent Literature

[0004] PTL 1: JP 08-311466 A

Summary of Invention

Technical Problem

[0005] In Patent Literature 1, however, only an investigation on a base oil has been made, and an investigation on a lubricating oil composition including additive formulation has not been made.

[0006] An object of the present invention is to provide a lubricating oil composition using a vegetable oil as a base oil, the composition being excellent in oxidation stability, and a method of using the composition and a method of producing the composition.

Solution to Problem

[0007] According to the present invention, there are provided the following items [1] to [3].

[1] A lubricating oil composition, comprising: a vegetable oil (A); a zinc dithiophosphate (B); and an amine-based antioxidant (C), wherein a total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to a total amount of the constituent fatty acids in the vegetable oil (A), wherein a content of the amine-based antioxidant (C) is 2.00 mass% or more with respect to a total amount of the lubricating oil composition, and wherein when the lubricating oil composition further comprises a phosphorus-free phenol-based antioxidant (D), a content of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

[2] A method of using the lubricating oil composition of the above-mentioned item [1], comprising using the lubricating oil composition as an industrial equipment oil.

[3] A method of producing a lubricating oil composition, comprising a step of mixing a vegetable oil (A), a zinc dithiophosphate (B), and an amine-based antioxidant (C) to prepare the lubricating oil composition, wherein a total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to a total amount of the constituent fatty acids in the vegetable oil (A), wherein a blending amount of the amine-based antioxidant (C) is 2.00 mass% or more with respect to a total amount of the lubricating oil composition, and wherein when the lubricating oil composition is further blended with a phosphorus-free phenol-based antioxidant (D), a blending amount of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

Advantageous Effects of Invention

[0008] According to the present invention, the lubricating oil composition using a vegetable oil as a base oil, the

composition being excellent in oxidation stability, and the method of using the composition and the method of producing the composition can be provided.

Description of Embodiments

[0009] The upper limit values and lower limit values of numerical ranges described herein may be arbitrarily combined. For example, when the range of "from A to B" and the range of "from C to D" are described as numerical ranges, the numerical range of "from A to D" and the numerical range of "from C to B" are also included in the scope of the present invention.

[0010] In addition, the numerical range of "from a lower limit value to an upper limit value" described herein means that a physical property value is the lower limit value or more and the upper limit value or less unless otherwise stated.

[0011] In addition, in this description, the numerical values of Examples are numerical values that may each be used as an upper limit value or a lower limit value.

[Aspects of Lubricating Oil Composition]

[0012] A lubricating oil composition of this embodiment includes: a vegetable oil (A); a zinc dithiophosphate (B); and an amine-based antioxidant (C).

[0013] The total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to the total amount of the constituent fatty acids in the vegetable oil (A).

[0014] In addition, the content of the amine-based antioxidant (C) is 2.00 mass% or more with respect to the total amount of the lubricating oil composition.

[0015] In addition, when the lubricating oil composition further includes a phosphorus-free phenol-based antioxidant (D), the content of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

[0016] The inventor of the present invention has made extensive investigations with a view to solving the above-mentioned problem. As a result, the inventor has found that the following items (I) to (IV) are important in the preparation of a lubricating oil composition excellent in oxidation stability through use of a vegetable oil as a base oil:

(I) such a vegetable oil that the total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil is less than 20 mass% with respect to the total amount of the constituent fatty acids is used;
(II) a zinc dithiophosphate and an amine-based antioxidant are incorporated;
(III) the content of the amine-based antioxidant is 2.00 mass% or more; and
(IV) the content of a phosphorus-free phenol-based antioxidant is less than 2.00 mass%.

[0017] Although the mechanism via which the lubricating oil composition of this embodiment is excellent in oxidation stability has not been elucidated, it is assumed that specific additive formulation satisfying the above-mentioned items (II) to (IV) exhibits an extremely excellent improving effect on the oxidation stability of a vegetable oil having a specific chemical structure satisfying the above-mentioned item (I) to make the oxidation stability of the lubricating oil composition excellent.

[0018] In the following description, the "vegetable oil (A)," the "zinc dithiophosphate (B)," the "amine-based antioxidant (C)," and the "phosphorus-free phenol-based antioxidant (D)" are also referred to as "component (A)," "component (B)," "component (C)," and "component (D)," respectively.

[0019] Although the lubricating oil composition of this embodiment may be formed only of the "component (A)," the "component (B)," and the "component (C)," the composition may or may not include the "component (D)," and one or more kinds selected from other components except the "component (A)," the "component (B)," the "component (C)," and the "component (D)" to the extent that the incorporation of such component does not deviate from the gist of the present invention.

[0020] In the lubricating oil composition of this embodiment, the total content of the "component (A)," the "component (B)," and the "component (C)" is preferably 35 mass% or more, more preferably 40 mass% or more, still more preferably 50 mass% or more, still further more preferably 60 mass% or more, yet still further more preferably 70 mass% or more, even more preferably 80 mass% or more, still even more preferably 90 mass% or more, yet still even more preferably 95 mass% or more with respect to the total amount of the lubricating oil composition.

[0021] The respective components for forming the lubricating oil composition of this embodiment are described in detail below.

<Vegetable Oil (A)>

[0022] The lubricating oil composition of this embodiment includes the vegetable oil (A) as a base oil.

[0023] The total content of linoleic acid and linolenic acid among the constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to the total amount of the constituent fatty acids in the vegetable oil (A) (hereinafter also referred to as "requirement 1").

[0024] When the total content of linoleic acid and linolenic acid is 20 mass% or more, the lubricating oil composition is liable to undergo oxidative degradation, and hence the oxidation stability of the lubricating oil composition is liable to be insufficient.

[0025] The term "constituent fatty acids of the vegetable oil (A)" means fatty acids in a compound for forming the vegetable oil in which the fatty acids and glycerin are ester-bonded to each other.

[0026] Herein, from the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, the total content of linoleic acid and linolenic acid is preferably 18 mass% or less, more preferably 16 mass% or less, still more preferably 15 mass% or less with respect to the total amount of the constituent fatty acids in the vegetable oil (A).

[0027] In addition, from the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, the content of oleic acid among the constituent fatty acids of the vegetable oil (A) is preferably 65 mass% or more with respect to the total amount of the constituent fatty acids in the vegetable oil (A) (hereinafter also referred to as "requirement 2"). From the same viewpoint, the content of oleic acid is more preferably 70 mass% or more, still more preferably 75 mass% or more with respect to the total amount of the constituent fatty acids in the vegetable oil (A). In addition, the content of oleic acid is typically less than 85 mass% with respect to the total amount of the constituent fatty acids in the vegetable oil (A).

[0028] In addition, from the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, the content of a saturated fatty acid among the constituent fatty acids of the vegetable oil (A) is preferably 3 mass% or more with respect to the total amount of the constituent fatty acids in the vegetable oil (A) (hereinafter also referred to as "requirement 3"). The content is more preferably 4 mass% or more, still more preferably 5 mass% or more.

[0029] Examples of the saturated fatty acid that may be incorporated into the constituent fatty acids of the vegetable oil (A) include one or more kinds selected from the group consisting of: lauric acid; myristic acid; palmitic acid; stearic acid; arachidic acid; behenic acid; and lignoceric acid. A particularly typical example thereof is palmitic acid.

[0030] A method of measuring the fatty acid composition of the vegetable oil (A) is, for example, a method including: extracting a lipid from the vegetable oil (A) with an organic solvent; evaporating the organic solvent after the extraction; then preparing a fatty acid methyl ester from the resultant lipid; and subjecting the fatty acid methyl ester to gas chromatography mass spectrometry (GC-MS analysis).

[0031] Examples of the vegetable oil (A) to be used in this embodiment include: a raw oil obtained by squeezing and extracting a natural vegetable oil raw material; a refined oil obtained by subjecting the raw oil to various kinds of refining treatment, such as filtration for removing a floating impurity in the raw oil, degumming for removing a phospholipid or the like, deacidification for removing a free fatty acid, decolorization for removing coloring matter, and dewaxing for removing a wax content; and a modified oil and fat obtained by subjecting the refined oil to treatment, such as hardening, fractionation, ester exchange, or hydrogenation.

[0032] Specific examples of the vegetable oil (A) include: vegetable oils, such as olive oil, sunflower oil (preferably high-oleic type), Carthamus Tinctorius oil (preferably high-oleic type), safflower oil (preferably high-oleic type), palm oil, palm kernel oil, and coconut oil; and plant-derived base oils such as an estolide ester.

[0033] The vegetable oil (A) may be formed only of one kind of vegetable oil, or may be a mixed vegetable oil including two or more kinds of vegetable oils. When the vegetable oil (A) is a mixed vegetable oil, the mixed vegetable oil only needs to satisfy the above-mentioned requirement 1, and the mixed vegetable oil preferably further satisfies at least one of the above-mentioned requirement 2 or 3, and more preferably satisfies all of the above-mentioned requirements 1, 2, and 3.

[0034] In the lubricating oil composition of this embodiment, the content of the vegetable oil (A) is preferably 30 mass% or more, more preferably 40 mass% or more, still more preferably 50 mass% or more, still further more preferably 60 mass% or more, yet still further more preferably 70 mass% or more, even more preferably 80 mass% or more, still even more preferably 85 mass% or more, yet still even more preferably 90 mass% or more with respect to the total amount of the lubricating oil composition. In addition, from the viewpoint of room for the blending of additives, such as the component (B) and the component (C), the content of the vegetable oil (A) is preferably 97.9 mass% or less with respect to the total amount of the lubricating oil composition.

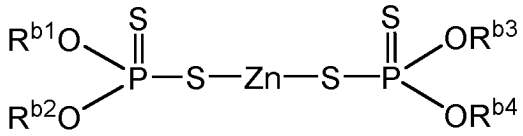
<Zinc Dithiophosphate (B)>

[0035] The lubricating oil composition of this embodiment includes the zinc dithiophosphate (B).

[0036] When the lubricating oil composition of this embodiment is free of the zinc dithiophosphate (B), the lubricating oil

composition is liable to undergo oxidative degradation, and hence the oxidation stability of the lubricating oil composition is liable to be insufficient.

[0037] The zinc dithiophosphate (B) is preferably, for example, a compound represented by the following general formula (b-1):



(b-1)

wherein

in the general formula (b-1), R^{h1} to R^{b4} each independently represent a monovalent hydrocarbon group. The hydrocarbon group is not particularly limited as long as the group is a monovalent hydrocarbon group, and from the viewpoint of improving the oxidation stability, preferred examples thereof include an alkyl group, an alkenyl group, a cycloalkyl group, and an aryl group. Among them, an alkyl group is preferred.

[0038] That is, the zinc dithiophosphate (B) to be used in this embodiment is preferably a zinc dialkyldithiophosphate.

[0039] The cycloalkyl group and the aryl group that may each be selected as each of R^{b1} to R^{b4} may be, for example, polycyclic groups, such as a decalyl group and a naphthyl group.

[0040] In addition, the monovalent hydrocarbon group that may be selected as each of R^{b1} to R^{b4} may be a group having a substituent containing an oxygen atom and/or a nitrogen atom, such as a hydroxy group, a carboxy group, an amino group, an amide group, a nitro group, or a cyano group, or may be partially substituted with a nitrogen atom, an oxygen atom, a halogen atom, or the like. When the monovalent hydrocarbon group is a cycloalkyl group or an aryl group, the group may further have a substituent, such as an alkyl group or an alkenyl group.

[0041] Although the alkyl group and the alkenyl group that may each be selected as each of R^{b1} to R^{b4} may be linear or branched, from the viewpoint of obtaining more excellent oxidation stability, each of the groups is preferably a primary or secondary group. Among them, a primary alkyl group or a secondary alkyl group is preferred, and a primary alkyl group is more preferred.

[0042] That is, the zinc dialkyldithiophosphate to be used in this embodiment is preferably a zinc dialkyldithiophosphate having a primary alkyl group or a secondary alkyl group, or a combination thereof, more preferably a primary zinc dialkyldithiophosphate or a secondary zinc dialkyldithiophosphate, or a combination thereof, still more preferably a primary zinc dialkyldithiophosphate.

[0043] From the viewpoint of improving the oxidation stability, when the monovalent hydrocarbon group is an alkyl group, the number of the carbon atoms of the hydrocarbon group represented by any one of R^{b1} to R^{b4} is preferably 1 or more, more preferably 2 or more, still more preferably 3 or more, and the upper limit thereof is preferably 24 or less, more preferably 18 or less, still more preferably 12 or less, still further more preferably 10 or less. When the monovalent hydrocarbon group is an alkenyl group, the number of the carbon atoms thereof is preferably 2 or more, more preferably 3 or more, and the upper limit thereof is preferably 24 or less, more preferably 18 or less, still more preferably 12 or less, still further more preferably 10 or less. In addition, when the monovalent hydrocarbon group is a cycloalkyl group, the number of the carbon atoms thereof is preferably 5 or more, and the upper limit thereof is preferably 20 or less. When the monovalent hydrocarbon group is an aryl group, the number of the carbon atoms thereof is preferably 6 or more, and the upper limit thereof is preferably 20 or less.

[0044] From the viewpoint of facilitating an improvement in oxidation stability of the lubricating oil composition, the content of the zinc dithiophosphate (B) is preferably 0.10 mass% or more, more preferably 0.20 mass% or more, still more preferably 0.30 mass% or more, still further more preferably 0.40 mass% or more, yet still further more preferably 0.50 mass% or more with respect to the total amount of the lubricating oil composition. In addition, from the viewpoint of suppressing sludge deposition, the content is preferably 1.00 mass% or less, more preferably 0.90 mass% or less, still more preferably 0.80 mass% or less.

[0045] The zinc dithiophosphates (B) may be used alone or in combination thereof.

<Amine-based Antioxidant (C)>

[0046] The lubricating oil composition of this embodiment includes the amine-based antioxidant (C). In addition, in the lubricating oil composition of this embodiment, the content of the amine-based antioxidant (C) needs to be 2.00 mass% or more with respect to the total amount of the lubricating oil composition.

[0047] When the content of the amine-based antioxidant (C) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition, the lubricating oil composition is liable to undergo oxidative degradation, and hence the oxidation stability of the lubricating oil composition is liable to be insufficient.

[0048] Herein, from the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil

composition, the content of the amine-based antioxidant (C) is preferably 3.00 mass% or more, more preferably 3.50 mass% or more, still more preferably 3.80 mass% or more with respect to the total amount of the lubricating oil composition.

[0049] In addition, from the viewpoint of appropriately facilitating an improvement in oxidation stability of the lubricating oil composition while suppressing excessive addition of the amine-based antioxidant (C), the content of the amine-based antioxidant (C) is preferably 8.00 mass% or less, more preferably 7.00 mass% or less, still more preferably 6.00 mass% or less with respect to the total amount of the lubricating oil composition.

[0050] An amine-based antioxidant generally used as an antioxidant for a lubricating oil composition may be used as the amine-based antioxidant (C).

[0051] Herein, from the viewpoint of improving the oxidation stability of the lubricating oil composition, the amine-based antioxidant (C) preferably contains a diphenylamine-based antioxidant (C1) and a naphthylamine-based antioxidant (C2).

[0052] In addition, from the same viewpoint, the total content of the diphenylamine-based antioxidant (C1) and the naphthylamine-based antioxidant (C2) is preferably from 50 mass% to 100 mass%, more preferably from 60 mass% to 100 mass%, still more preferably from 70 mass% to 100 mass%, still further more preferably from 80 mass% to 100 mass%, yet still further more preferably from 90 mass% to 100 mass%, even more preferably from 95 mass% to 100 mass% with respect to the total amount of the amine-based antioxidant (C).

[0053] The diphenylamine-based antioxidant (C1) and the naphthylamine-based antioxidant (C2) are described in detail below.

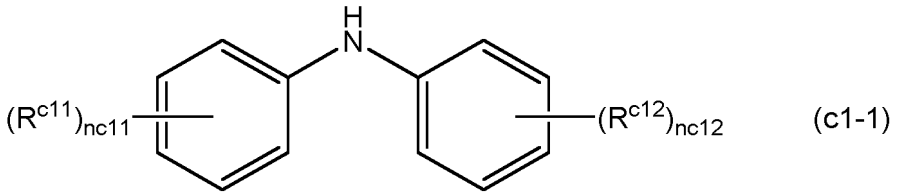
[0054] In the following description, the "diphenylamine-based antioxidant (C1)" and the "naphthylamine-based antioxidant (C2)" are also referred to as "component (C1)" and "component (C2)," respectively.

(Diphenylamine-based Antioxidant (C1))

[0055] A diphenylamine-based antioxidant generally used as an antioxidant for a lubricating oil composition may be used as the diphenylamine-based antioxidant (C1).

[0056] The diphenylamine-based antioxidants (C1) may be used alone or in combination thereof.

[0057] Herein, in the lubricating oil composition of this embodiment, from the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, the diphenylamine-based antioxidant (C1) is preferably a compound represented by the following general formula (c1-1):



(c1-1)

wherein

in the general formula (c1-1), R^{c11} and R^{c12} each independently represent an alkyl group having 1 to 30 carbon atoms.

[0058] When the number of the carbon atoms of the alkyl group is from 1 to 30, an improvement in oxidation stability of the lubricating oil composition can be further facilitated.

[0059] From the viewpoint of further facilitating improvements in effects of the present invention, the numbers of the carbon atoms of the alkyl groups that may be selected as R^{c11} and R^{c12} are each independently preferably from 1 to 20, more preferably from 4 to 16, still more preferably from 4 to 14.

[0060] Specific examples of the alkyl group that may be selected as each of R^{c11} and R^{c12} include a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, an undecyl group, a dodecyl group, a tridecyl group, a tetradecyl group, a pentadecyl group, a hexadecyl group, a heptadecyl group, an octadecyl group, a nonadecyl group, an icosyl group, a henicosyl group, a docosyl group, a tricosyl group, a tetracosyl group, a pentacosyl group, a hexacosyl group, a heptacosyl group, an octacosyl group, a nonacosyl group, and a triacontyl group. Those groups may be linear or branched.

[0061] In the general formula (c1-1), nc11 and nc12 each independently represent an integer of from 1 to 5.

[0062] From the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, nc11 and nc12 each independently represent preferably from 1 to 3, more preferably 1 or 2, still more preferably 1.

[0063] The compounds each represented by the general formula (c1-1) may be used alone or in combination thereof.

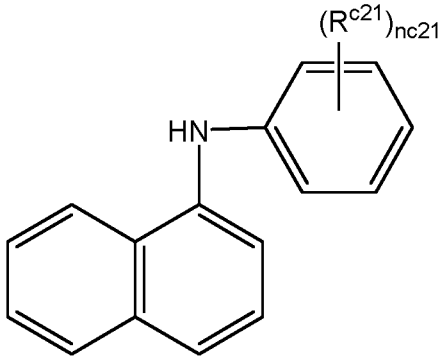
(Naphthylamine-based Antioxidant (C2))

[0064] A naphthylamine-based antioxidant generally used as an antioxidant for a lubricating oil composition may be

used as the naphthylamine-based antioxidant (C2).

[0065] The naphthylamine-based antioxidants (C2) may be used alone or in combination thereof.

[0066] Herein, in the lubricating oil composition of this embodiment, from the viewpoint of further facilitating improvements in effects of the present invention, the naphthylamine-based antioxidant (C2) is preferably a compound represented by the following general formula (c2-1):



(c2-1)

wherein

in the general formula (c2-1), R^{c21} represents an alkyl group having 1 to 30 carbon atoms.

[0067] When the number of the carbon atoms of the alkyl group is from 1 to 30, the effects of the present invention are easily improved.

[0068] From the viewpoint of further facilitating improvements in effects of the present invention, the numbers of the carbon atoms of the alkyl group that may be selected as R^{c21} are each independently preferably from 1 to 20, more preferably from 4 to 16, still more preferably from 4 to 14.

[0069] Specific examples of the alkyl group that may be selected as R^{c21} include those given as the examples of the alkyl group that may be selected as each of R^{c11} and R^{c12}. The alkyl group may be linear or branched.

[0070] In the general formula (c2-1), nc21s each independently represent an integer of from 1 to 5.

[0071] From the viewpoint of further facilitating improvements in effects of the present invention, nc21s each independently represent preferably from 1 to 3, more preferably 1 or 2, still more preferably 1.

[0072] The compounds each represented by the general formula (c2-1) may be used alone or in combination thereof.

(Content Ratio between Component (C1) and Component (C2))

[0073] In the lubricating oil composition of this embodiment, when the amine-based antioxidant (C) contains the diphenylamine-based antioxidant (C1) and the naphthylamine-based antioxidant (C2), a content ratio [(C1)/(C2)] between the diphenylamine-based antioxidant (C1) and the naphthylamine-based antioxidant (C2) is preferably from 0.10 to 9.00, more preferably from 0.25 to 4.00, still more preferably from 0.50 to 2.00, still further more preferably from 0.75 to 1.25 in terms of mass ratio from the viewpoint of further facilitating improvements in effects of the present invention.

<Content Ratio between Component (B) and Component (C)>

[0074] In the lubricating oil composition of this embodiment, a content ratio [(B)/(C)] between the zinc dithiophosphate (B) and the amine-based antioxidant (C) is preferably from 0.01 to 0.50, more preferably from 0.05 to 0.30, still more preferably from 0.10 to 0.20 in terms of mass ratio from the viewpoint of further facilitating improvements in effects of the present invention.

<Phosphorus-free Phenol-based Antioxidant (D)>

[0075] The lubricating oil composition of this embodiment may further include the phosphorus-free phenol-based antioxidant (D). However, when the lubricating oil composition of this embodiment further includes the phosphorus-free phenol-based antioxidant (D), the content of the phosphorus-free phenol-based antioxidant (D) needs to be less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

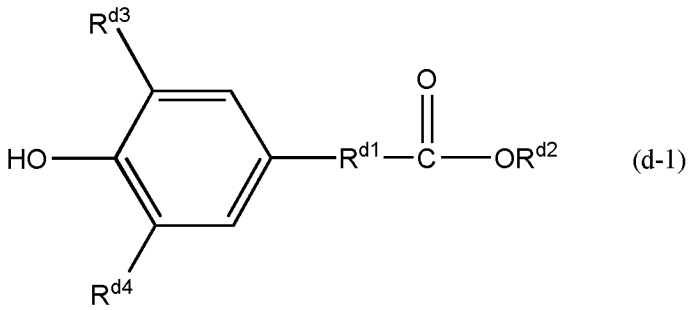
[0076] In the course of an investigation on the effectiveness of an antioxidant on the vegetable oil (A), the inventors of the present invention have found that when the content of the phosphorus-free phenol-based antioxidant (D) is 2.00 mass% or more, the oxidation stability of the lubricating oil composition largely reduces.

[0077] Accordingly, the content of the phosphorus-free phenol-based antioxidant (D) is preferably as small as possible.

[0078] Specifically, the content of the phosphorus-free phenol-based antioxidant (D) is preferably less than 1.50 mass%, more preferably less than 1.00 mass%, still more preferably less than 0.50 mass%, still further more preferably less than 0.10 mass%, yet still further more preferably less than 0.05 mass%, even more preferably less than 0.01 mass% with respect to the total amount of the lubricating oil composition. It is most preferred that the lubricating oil composition be free of the phosphorus-free phenol-based antioxidant (D).

[0079] The phosphorus-free phenol-based antioxidant (D) is, for example, a phosphorus-free phenol-based antioxidant having a phenol skeleton to be generally used as an antioxidant for a lubricating oil composition. For example, the phosphorus-free phenol-based antioxidant (D) encompasses not only a compound, which has a phenol skeleton and is formed only of a carbon atom, a hydrogen atom, and an oxygen atom, but also a compound (sulfur-containing phenol compound), which has a phenol skeleton and has a sulfur atom in addition to a carbon atom, a hydrogen atom, and an oxygen atom.

[0080] Herein, in the lubricating oil composition of this embodiment, from the viewpoint of improving the oxidation stability of the lubricating oil composition, the content of a compound represented by the following general formula (d-1), the compound serving as the phosphorus-free phenol-based antioxidant (D), is particularly preferably as small as possible:



(d-1)

wherein

in the general formula (d-1), R^{d1} represents an alkylene group having 1 to 5 carbon atoms.

[0081] The number of the carbon atoms of the alkylene group that may be selected as R^{d1} may be from 1 to 4, may be from 1 to 3, or may be 1 or 2.

[0082] Specific examples of the alkylene group that may be selected as R^{d1} include: linear alkylene groups, such as a methylene group, an ethylene group, a n-propylene group, a n-butylene group, and a n-pentylene group; and branched alkylene groups, such as an isopropylene group, an isobutylene group, a sec-butylene group, a tert-butylene group, an isopentylene group, and a neopentylene group.

[0083] In the general formula (d-1), R^{d2} represents an alkyl group having 1 to 25 carbon atoms.

[0084] The number of the carbon atoms of the alkyl group that may be selected as R^{d2} may be from 2 to 20, may be from 4 to 15, or may be from 6 to 10.

[0085] Specific examples of the alkyl group that may be selected as R^{d2} include a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, an undecyl group, a dodecyl group, a tridecyl group, a tetradecyl group, a pentadecyl group, a hexadecyl group, a heptadecyl group, an octadecyl group, a nonadecyl group, an icosyl group, a henicosyl group, a docosyl group, a tricosyl group, a tetracosyl group, and a pentacosyl group. Those groups may be linear or branched.

[0086] In the general formula (d-1), R^{d3} and R^{d4} each independently represent a hydrogen atom or an alkyl group having 1 to 30 carbon atoms.

[0087] Examples of the alkyl group that may be selected as each of R^{d3} and R^{d4} include the same examples as those of the alkyl group that may be selected as each of R^{c1} and R^{c2} described above.

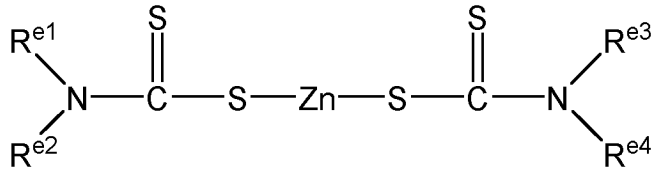
[0088] However, the numbers of the carbon atoms of the alkyl groups that may be selected as R^{d3} and R^{d4} may each independently be from 1 to 20, may each independently be from 1 to 10, or may each independently be from 1 to 6.

[0089] Herein, the phosphorus-free phenol-based antioxidant (D) may have a hindered phenol skeleton. Accordingly, the alkyl group that may be selected as each of R^{d3} and R^{d4} may be a branched alkyl group, may be a branched alkyl group having 1 to 6 carbon atoms, or may be a tert-butyl group.

<Zinc Dithiocarbamate (E)>

[0090] The lubricating oil composition of this embodiment preferably further includes a zinc dithiocarbamate (E). When the lubricating oil composition further includes the zinc dithiocarbamate (E), the oxidation stability of the lubricating oil composition can be further improved.

[0091] The zinc dithiocarbamate (E) is preferably, for example, a compound represented by the following general formula (e-1):



(e-1)

wherein
in the general formula (e-1), R^{e1} to R^{e4} each independently represent a monovalent hydrocarbon group. The same groups as those of R^{b1} to R^{b4} in the general formula (b-1) may each be used as the monovalent hydrocarbon group.

[0092] In addition, from the viewpoint of facilitating an improvement in oxidation stability of an additive for a lubricating oil, an alkyl group that may be selected as each of R^{e1} to R^{e4} is preferably a primary alkyl group or a secondary alkyl group, or a combination thereof, more preferably a primary alkyl group.

[0093] In addition, the number of the carbon atoms of the alkyl group that may be selected as each of R^{e1} to R^{e4} is preferably from 3 to 12, more preferably from 3 to 10, still more preferably from 3 to 8.

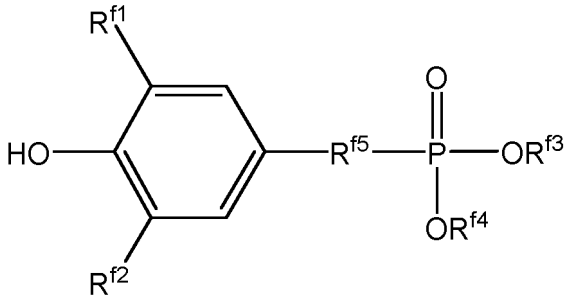
[0094] Specifically, a primary zinc dithiocarbamate or a secondary zinc dithiocarbamate, or a combination thereof is more preferred, and a primary zinc dithiocarbamate is more preferred.

[0095] From the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, the content of the zinc dithiocarbamate (E) is preferably 0.01 mass% or more, more preferably 0.05 mass% or more, still more preferably 0.08 mass% or more with respect to the total amount of the lubricating oil composition. In addition, from the viewpoint of a balance between the addition amount of the zinc dithiocarbamate (E) and the improving effect thereof on the oxidation stability, the content of the zinc dithiocarbamate (E) is preferably 1.00 mass% or less, more preferably 0.50 mass% or less, still more preferably 0.30 mass% or less with respect to the total amount of the lubricating oil composition.

[0096] The zinc dithiocarbamates (E) may be used alone or in combination thereof.

(Phosphorus-containing Phenol-based Antioxidant (F))

[0097] The lubricating oil composition of this embodiment preferably further includes a phosphorus-containing phenol-based antioxidant (F). This is because the phosphorus-containing phenol-based antioxidant (F) can interact with the amine-based antioxidant (C) to further improve anti-oxidation performance exhibited by the amine-based antioxidant (C). From the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, the phosphorus-containing phenol-based antioxidant (F) is preferably, for example, a compound represented by the following general formula (f-1):



(f-1)

wherein
in the general formula (f-1), R^{f1}, R^{f2}, R^{f3}, and R^{f4} each independently represent a hydrogen atom or an alkyl group having 1 to 30 carbon atoms.

[0098] Examples of the alkyl group that may be selected as each of R^{f1}, R^{f2}, R^{f3}, and R^{f4} include the same examples as those of the alkyl group that may be selected as each of R^{c1} and R^{c2} described above.

[0099] However, the numbers of the carbon atoms of the alkyl groups that may be selected as R^{f1}, R^{f2}, R^{f3}, and R^{f4} are each independently preferably from 1 to 20, more preferably from 1 to 10, still more preferably from 1 to 6.

[0100] Herein, the phosphorus-containing phenol-based antioxidant (F) preferably has a hindered phenol skeleton. Accordingly, the alkyl group that may be selected as each of R^{f1} and R^{f2} is preferably a branched alkyl group, more preferably a branched alkyl group having 1 to 6 carbon atoms, still more preferably a tert-butyl group.

[0101] In the general formula (f-1), R^{f5} represents an alkylene group having 1 to 5 carbon atoms.

[0102] The number of the carbon atoms of the alkylene group that may be selected as R^{f5} is preferably from 1 to 4, more preferably from 1 to 3, still more preferably 1 or 2, still further more preferably 1.

[0103] Specific examples of the alkylene group that may be selected as R^{f5} include: linear alkylene groups, such as a methylene group, an ethylene group, a n-propylene group, a n-butylene group, and a n-pentylene group; and branched alkylene groups, such as an isopropylene group, an isobutylene group, a sec-butylene group, a tert-butylene group, an isopentylene group, and a neopentylene group. Among them, a methylene group is preferred.

[0104] From the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition, the content of the phosphorus-containing phenol-based antioxidant (F) is preferably 0.01 mass% or more, more preferably 0.05 mass% or more, still more preferably 0.08 mass% or more with respect to the total amount of the lubricating oil composition. In addition, the content of the phosphorus-containing phenol-based antioxidant (F) is preferably 1.00 mass% or less, more preferably 0.50 mass% or less, still more preferably 0.30 mass% or less with respect to the total amount of the lubricating oil composition.

<Other Component>

[0105] The lubricating oil composition of this embodiment may include any other component except the components (A) to (F) to the extent that the effects of the present invention are not impaired.

[0106] Examples of the other component include a metal deactivator, a rust inhibitor, and an antifoaming agent. Those components may be used alone or in combination thereof.

[0107] In addition, a detergent dispersant may be further incorporated as the other component.

[0108] In addition, one or more kinds selected from a mineral oil and a synthetic oil may be further incorporated as the other component.

(Metal Deactivator)

[0109] Examples of the metal deactivator include a benzotriazole-based compound, a tolyltriazole-based compound, a thiadiazole-based compound, an imidazole-based compound, and a pyrimidine-based compound.

[0110] When the lubricating oil composition of this embodiment includes the metal deactivator, the content of the metal deactivator is preferably from 0.01 mass% to 5.0 mass%, more preferably from 0.15 mass% to 3.0 mass% with respect to the total amount of the lubricating oil composition.

[0111] The metal deactivators may be used alone or in combination thereof.

(Rust Inhibitor)

[0112] Examples of the rust inhibitor include a sulfonic acid metal salt, an organic phosphorous acid ester, an organic phosphoric acid ester, an organic phosphoric acid metal salt, an alkenylsuccinic acid ester, and an alkenylsuccinic acid polyhydric alcohol ester.

[0113] The sulfonic acid metal salt is a metal salt of any of various sulfonic acids. Examples of the various sulfonic acids for forming the sulfonic acid metal salt include an aromatic petroleum sulfonic acid, an alkyl sulfonic acid, an aryl sulfonic acid, and an alkylaryl sulfonic acid. More specifically, preferred examples thereof include dodecylbenzenesulfonic acid, dilaurylcetylbenzenesulfonic acid, benzenesulfonic acid substituted with paraffin wax, benzenesulfonic acid substituted with polyolefin, benzenesulfonic acid substituted with polyisobutylene, naphthalenesulfonic acid, and dinonylnaphthalenesulfonic acid. Among them, dinonylnaphthalenesulfonic acid is more preferred.

[0114] A metal for forming the sulfonic acid metal salt is preferably, for example, sodium, magnesium, calcium, zinc, or barium. Among them, calcium or barium is preferred, and barium is more preferred from the viewpoints of a rust-inhibiting property, storage stability, and ease of availability.

[0115] When the lubricating oil composition of this embodiment includes the rust inhibitor, the content of the rust inhibitor is preferably from 0.01 mass% to 10.0 mass%, more preferably from 0.030 mass% to 5.00 mass% with respect to the total amount of the lubricating oil composition.

[0116] The rust inhibitors may be used alone or in combination thereof.

(Antifoaming Agent)

[0117] Examples of the antifoaming agent include: silicone-based antifoaming agents; fluorine-based antifoaming agents, such as a fluorosilicone oil and a fluoroalkyl ether; and polyacrylate-based antifoaming agents.

[0118] When the lubricating oil composition of this embodiment includes the antifoaming agent, the content (active ingredient amount) of the antifoaming agent is preferably from 0.001 mass% to 0.50 mass%, more preferably from 0.01 mass% to 0.30 mass% with respect to the total amount of the lubricating oil composition.

[0119] The antifoaming agents may be used alone or in combination thereof.

(Detergent Dispersant)

[0120] Examples of the detergent dispersant include a metal sulfonate, a metal salicylate, a metal phenate, and succinimide.

[0121] The content of the detergent dispersant is typically from 0.01 mass% to 10 mass%, preferably from 0.1 mass% to 5 mass% with respect to the total amount of the lubricating oil composition.

(Mineral Oil and Synthetic Oil)

[0122] Examples of the mineral oil include: a normal-pressure residual oil obtained by distilling a crude oil, such as a paraffin-based crude oil, an intermediate base crude oil, or a naphthene-based crude oil, under normal pressure; a distillate oil obtained by distilling such normal-pressure residual oil under reduced pressure; and a mineral oil obtained by subjecting the distillate oil to one or more of refining treatments, such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, contact dewaxing, and hydrorefining.

[0123] Examples of the synthetic oil include: polyolefins, such as polybutene, a 1-octene oligomer, and a 1-decene oligomer, and hydrogenated products thereof, and an ethylene-α-olefin copolymer; isoparaffin; various esters, such as a polyol ester and a dibasic acid ester; various ethers such as polyphenyl ether; polyalkylene glycols; alkylbenzenes; alkylnaphthalenes; and GTL base oils obtained by isomerizing waxes (gas-to-liquid (GTL) waxes) produced from natural gas by a Fischer-Tropsch process.

[0124] The mineral oils may be used alone or in combination thereof. The synthetic oils may also be used alone or in combination thereof. In addition, one or more kinds of the mineral oils and one or more kinds of the synthetic oils may be used in combination.

[0125] When the lubricating oil composition of this embodiment includes one or more kinds selected from the mineral oil and the synthetic oil, from the viewpoint of the gist of the present invention into which the concept of carbon neutrality is introduced, its content is preferably 100 parts by mass or less, more preferably 50 parts by mass or less, still more preferably 10 parts by mass or less with respect to 100 parts by mass of the vegetable oil (A).

[Physical Properties of Lubricating Oil Composition]

<40°C Kinematic Viscosity and Viscosity Index of Lubricating Oil Composition>

[0126] The 40°C kinematic viscosity of the lubricating oil composition of this embodiment is preferably from 19.8 mm^2/s to 352 mm^2/s, more preferably from 28.8 mm^2/s to 242 mm^2/s, still more preferably from 28.8 mm^2/s to 165 mm^2/s.

<Acid Value after ISOT Test>

[0127] The acid value of the lubricating oil composition of this embodiment after an ISOT test described in Examples to be described later is preferably 20.0 mgKOH/g or less, more preferably 15.0 mgKOH/g or less, still more preferably 10.0 mgKOH/g or less.

<Millipore Value after ISOT Test>

[0128] The millipore value of the lubricating oil composition of this embodiment after an ISOT test described in Examples to be described later is preferably 20 mg/100 mL or less, more preferably 10 mg/100 mL or less, still more preferably 5 mg/100 mL or less.

<Carbon Amount after Panel Coking Test>

[0129] The carbon amount of the lubricating oil composition of this embodiment after a panel coking test described in Examples to be described later is preferably 60 mg or less, more preferably 50 mg or less, still more preferably 40 mg or less.

<Zinc Amount>

[0130] From the viewpoint of further facilitating an improvement in oxidation stability of the lubricating oil composition of this embodiment, the zinc amount of the lubricating oil composition is preferably from 0.01 mass% to 0.15 mass%, more

preferably from 0.02 mass% to 0.12 mass%, still more preferably from 0.03 mass% to 0.10 mass% with respect to the total amount of the lubricating oil composition.

[0131] In this description, the zinc amount in the lubricating oil composition may be measured in conformity with, for example, JPI-5S-38-03.

<Molybdenum Amount>

[0132] The molybdenum amount of the lubricating oil composition of this embodiment is preferably less than 0.01 mass%, more preferably less than 0.001 mass% with respect to the total amount of the lubricating oil composition. It is still more preferred that the composition be free of molybdenum.

[0133] In this description, the molybdenum amount in the lubricating oil composition may be measured in conformity with, for example, JPI-5S-38-03.

<Viscosity Index Improver>

[0134] The content of the viscosity index improver in the lubricating oil composition of this embodiment is preferably less than 0.01 mass%, more preferably less than 0.001 mass% with respect to the total amount of the lubricating oil composition. It is still more preferred that the composition be free of the viscosity index improver.

[Method of producing Lubricating Oil Composition]

[0135] A method of producing a lubricating oil composition of this embodiment is not particularly limited.

[0136] For example, the method of producing a lubricating oil composition of this embodiment includes a step of mixing a vegetable oil (A), a zinc dithiophosphate (B), and an amine-based antioxidant (C) to prepare the lubricating oil composition.

[0137] The total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to the total amount of the constituent fatty acids in the vegetable oil (A).

[0138] The blending amount of the amine-based antioxidant (C) is 2.00 mass% or more with respect to the total amount of the lubricating oil composition.

[0139] When the lubricating oil composition is further blended with a phosphorus-free phenol-based antioxidant (D), the blending amount of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

[0140] The production method may further include a step of blending one or more kinds selected from a zinc dithiocarbamate (E) and a phosphorus-containing phenol-based antioxidant (F) as required.

[0141] In addition, the production method may further include a step of blending the above-mentioned other component as required.

[0142] Although a method of mixing the respective components is not particularly limited, for example, a method including blending the respective components into the vegetable oil (A) is available. In addition, each of the components may be blended after a diluting oil or the like has been added to bring the component into a solution (dispersion) form. After having been blended, the respective components are preferably dispersed in a uniform manner through stirring by a known method.

[0143] Preferred aspects of the component (A), the component (B), the component (C), the component (D), the component (E), and the component (F) are as described above.

[0144] In addition, the blending amounts and blending ratios of the component (A), the component (B), the component (C), the component (D), the component (E), and the component (F) are preferably set to blending amounts and blending ratios corresponding to preferred contents and preferred content ratios of the component (A), the component (B), the component (C), the component (D), the component (E), and the component (F) described above.

[Applications of Lubricating Oil Composition]

[0145] The lubricating oil composition according to this embodiment is excellent in oxidation stability. Accordingly, the lubricating oil composition of this embodiment hardly causes various problems such as the occurrence of sludge resulting from its oxidative degradation, and hence the lubricating oil composition can be stably used over a long time period.

[0146] Accordingly, the lubricating oil composition of this embodiment is used as, for example, a lubricating oil composition for machinery and equipment in which excellent oxidation stability is required. Specifically, the composition is preferably used as an industrial equipment oil. The industrial equipment oil is, for example, a hydraulic oil, a turbine oil, a compressor oil, a machine tool oil, or a gear oil.

[0147] From the viewpoint of the oxidation stability of the lubricating oil composition according to this embodiment, the lubricating oil composition according to this embodiment may be suitably used as a rotary air compressor oil or a

reciprocating air compressor oil among them, and may be particularly suitably used as a reciprocating air compressor oil.

[0148] Accordingly, the lubricating oil composition according to this embodiment provides the following usage methods (1) to (4):

(1) a method of using the lubricating oil composition according to this embodiment, including using the lubricating oil composition as an industrial equipment oil;
(2) a method of using the lubricating oil composition according to this embodiment, including using the lubricating oil composition as a hydraulic oil, a turbine oil, a compressor oil, a machine tool oil, or a gear oil;
(3) a method of using the lubricating oil composition according to this embodiment, including using the lubricating oil composition as a rotary air compressor oil or a reciprocating air compressor oil; and
(4) a method of using the lubricating oil composition according to this embodiment, including using the lubricating oil composition as a reciprocating air compressor oil.

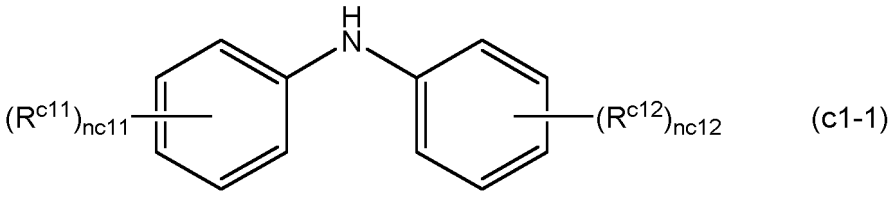
[One Aspect of the Present Invention to be provided]

[0149] According to one aspect of the present invention, there are provided the following items [1] to [12].

[1] A lubricating oil composition, including:

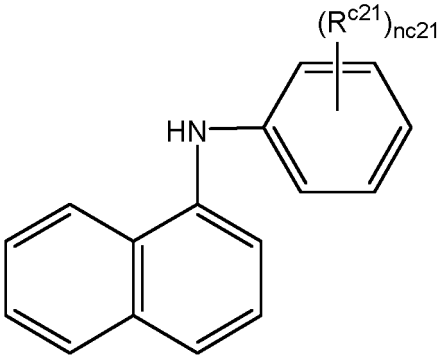
a vegetable oil (A);
a zinc dithiophosphate (B); and
an amine-based antioxidant (C),
wherein a total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to a total amount of the constituent fatty acids in the vegetable oil (A),
wherein a content of the amine-based antioxidant (C) is 2.00 mass% or more with respect to a total amount of the lubricating oil composition, and
wherein when the lubricating oil composition further includes a phosphorus-free phenol-based antioxidant (D), a content of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

[2] The lubricating oil composition according to the above-mentioned item [1], wherein a content of oleic acid among the constituent fatty acids of the vegetable oil (A) is 65 mass% or more with respect to the total amount of the constituent fatty acids in the vegetable oil (A).
[3] The lubricating oil composition according to the above-mentioned item [1] or [2], wherein a content of the zinc dithiophosphate (B) is 0.10 mass% or more with respect to the total amount of the lubricating oil composition.
[4] The lubricating oil composition according to any one of the above-mentioned items [1] to [3], wherein the amine-based antioxidant (C) contains a diphenylamine-based antioxidant (C1) and a naphthylamine-based antioxidant (C2).
[5] The lubricating oil composition according to the above-mentioned item [4], wherein the diphenylamine-based antioxidant (C1) is a compound represented by the following general formula (c1-1):



(c1-1)

wherein in the general formula (c1-1), R^{c11} and R^{c12} each independently represent an alkyl group having 1 to 30 carbon atoms, and nc11 and nc12 each independently represent an integer of from 1 to 5.
[6] The lubricating oil composition according to the above-mentioned item [4] or [5], wherein the naphthylamine-based antioxidant (C2) is a compound represented by the following general formula (c2-1):



(c2-1)

wherein in the general formula (c2-1), R^{c21} represents an alkyl group having 1 to 30 carbon atoms, and nc21 represents an integer of from 1 to 5.

[7] The lubricating oil composition according to any one of the above-mentioned items [1] to [6], further including a zinc dithiocarbamate (E).

[8] The lubricating oil composition according to any one of the above-mentioned items [1] to [7], further including a phosphorus-containing phenol-based antioxidant (F).

[9] The lubricating oil composition according to any one of the above-mentioned items [1] to [8], further including one or more kinds selected from the group consisting of: a metal deactivator; a rust inhibitor; and an antifoaming agent.

[10] The lubricating oil composition according to any one of the above-mentioned items [1] to [9], wherein the lubricating oil composition is used as an industrial equipment oil.

[11] A method of using the lubricating oil composition of any one of the above-mentioned items [1] to [9], including using the lubricating oil composition as an industrial equipment oil.

[12] A method of producing a lubricating oil composition, including a step of mixing a vegetable oil (A), a zinc dithiophosphate (B), and an amine-based antioxidant (C) to prepare the lubricating oil composition,

wherein a total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to a total amount of the constituent fatty acids in the vegetable oil (A),
wherein a blending amount of the amine-based antioxidant (C) is 2.00 mass% or more with respect to a total amount of the lubricating oil composition, and
wherein when the lubricating oil composition is further blended with a phosphorus-free phenol-based antioxidant (D), a blending amount of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

Examples

[0150] The present invention is specifically described by way of Examples below. However, the present invention is not limited to Examples below.

[Methods of measuring Various Physical Property Values]

[0151] The respective properties of base oils used in Examples and Comparative Examples are measured in accordance with the following procedures.

<40°C Kinematic Viscosity and Viscosity Index>

[0152] A 40°C kinematic viscosity and a viscosity index were measured and calculated in conformity with JIS K2283:2000.

[Examples 1 to 3 and Comparative Examples 1 to 5]

[0153] The following respective components were mixed to prepare lubricating oil compositions each having composition shown in Table 1.

[0154] The numerical values of blending composition in Table 1 are each represented in the unit of "mass%".

<Vegetable Oil (A)>

[0155]

- Refined olive oil (manufactured by Summit Oil Mill, product name: OLIVE OIL RS)
- High-oleic sunflower oil (manufactured by Summit Oil Mill, product name: HIGH-OLEIC

SUNFLOWER OIL)

<Vegetable Oil (A')>

[0156]

- Rapeseed white squeezed oil (manufactured by Summit Oil Mill, product name: RAPESEED SHIRASHIME OIL)
- Salad oil (manufactured by Summit Oil Mill, product name: HIGH-OLEIC SAFFLOWER OIL)

[0157] In Table 1, the term "Other component" in constituent fatty acids of the vegetable oil (A) and the vegetable oil (A') refers to any other fatty acid to be incorporated except linoleic acid, linolenic acid, oleic acid, and palmitic acid among the constituent fatty acids of the vegetable oils.

<Zinc Dithiophosphate (B)>

[0158] A zinc dialkyldithiophosphate represented by the general formula (b-1) in which R^{b1} to R^{b4} each represented an alkyl group was used as the zinc dithiophosphate (B).

[0159] The zinc dialkyldithiophosphate is a compound containing a primary zinc dialkyldithiophosphate as a main component. The alkyl groups for forming the zinc dialkyldithiophosphate include a primary alkyl group having 6 carbon atoms (a hexyl group) as a main component, and partially include an isobutyl group and an isopropyl group.

[0160] The content of zinc in the zinc dialkyldithiophosphate is 8.5 mass%.

<Amine-based Antioxidant (C)>

• "Dioctyldiphenylamine"

[0161] Dioctyldiphenylamine is a compound corresponding to the diphenylamine-based antioxidant (C1) represented by the general formula (c1-1) in which R^{c11} and R^{c12} represent octyl groups, and nc11=nc12=1.

• "p-tert-Octylphenyl-1-naphthylamine"

[0162] p-tert-Octylphenyl-1-naphthylamine is a compound corresponding to the naphthylamine-based antioxidant (C2) represented by the general formula (c2-1) in which R^{c21} represents a tert-octyl group, and nc21=1.

<Phosphorus-free Phenol-based Antioxidant (D)>

• "Benzenepropanoic acid 3,5-bis(1,1-dimethylethyl)-4-hydroxy-alkyl ester"

[0163] A benzenepropanoic acid 3,5-bis(1,1-dimethylethyl)-4-hydroxy-alkyl ester is a compound represented by the general formula (d-1) in which R^{d1} represents an alkylene group having 2 carbon atoms, R^{d2} represents an alkyl group having 8 carbon atoms, and R^{d3} and R^{d4} represent tert-butyl groups.

<Zinc Dithiocarbamate (E)>

[0164] Zinc diamyldithiocarbamate was used as the zinc dithiocarbamate (E). Zinc diamyldithiocarbamate is a compound represented by the general formula (e-1) in which R^{e1} to R^{e4} each represent an amyl group (a pentyl group, that is, a primary alkyl group having 5 carbon atoms).

[0165] The content of zinc in zinc diamyldithiocarbamate is 6.2 mass%.

<Phosphorus-containing Phenol-based Antioxidant (F)>

• "Diethyl 3,5-di-tert-butyl-4-hydroxybenzyl phosphonate"

[0166] Diethyl 3,5-di-tert-butyl-4-hydroxybenzyl phosphonate is a compound represented by the general formula (f-1) in which R^{f1} and R^{f2} represent tert-butyl groups, R^{f3} and R^{f4} represent ethyl groups, and R^{f5} represents a methylene group.

<Other Component>

[0167]

- Carboxylic acid amide
- Alkenylsuccinic acid polyhydric alcohol ester
- Dinonylnaphthalenesulfonic acid barium salt (50% diluted product)
- Silicone-based antifoaming agent (100-fold diluted product)

<Evaluation>

(1) ISOT Test

[0168] A copper piece and an iron piece were loaded as catalysts into a test oil (lubricating oil composition), and an ISOT test in conformity with JIS K 2514-1:2013 was performed to forcibly degrade the test oil. A test temperature (oil temperature) was set to 120°C. Then, the increase rate of the 40°C kinematic viscosity of the test oil 240 hours after the start of the ISOT test, the acid value (mgKOH/g) thereof, and the millipore value (mg/100 mL) thereof were measured.

[0169] The increase rate of the 40°C kinematic viscosity represented in the unit of percentage was obtained by calculating the percentage by which the 40°C kinematic viscosity of the lubricating oil composition after the ISOT test (post-test oil) increased as compared to that of the lubricating oil composition before the ISOT test (new oil). It can be said that as the increase rate of the 40°C kinematic viscosity becomes lower, the lubricating oil composition becomes more excellent in oxidation stability.

[0170] The acid value of the lubricating oil composition after the ISOT test was measured in conformity with the indicator method of JIS K2501:2003.

[0171] It can be said that as the acid value after the ISOT test becomes lower, the lubricating oil composition becomes more excellent in oxidation stability.

[0172] The millipore value of the lubricating oil composition after the ISOT test was measured in conformity with ASTM D7873 by using a membrane filter manufactured by Millipore Corporation, the filter having an average pore diameter of 1.0 μm.

[0173] It can be said that as the millipore value becomes lower, the lubricating oil composition becomes more excellent in oxidation stability.

(2) Panel Coking Test

[0174] A test was performed in conformity with Fed. Test Method Std. 791-3462 under the conditions of a panel temperature of 270°C and an oil temperature of 80°C in a cycle formed of a splash time of 15 seconds and a stop time of 45 seconds for 3 hours. After the completion of the test, the amount of carbon adhering to a panel (carbon adhesion amount (mg)) was evaluated.

[0175] It can be said that as the carbon adhesion amount becomes smaller, the panel becomes more excellent in oxidation stability.

[0176] The results are shown in Table 1.

[0177] The content of zinc in each of the lubricating oil compositions of Examples 1 and 3 is 0.0657 mass% (with respect to the total amount of the lubricating oil composition, calculated value), and the content of zinc in the lubricating oil composition of Example 2 is 0.0595 mass% (with respect to the total amount of the lubricating oil composition, calculated value).

Table 1

			Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Composition of constituent fatty acids of vegetable oils (A) and (A') (unit: mass%)		Palmitic acid	11	11	5	4	7	11	5	5
		Oleic acid	77	77	78	63	13	77	78	78
		Linoleic acid	7	7	14	19	76	7	14	14
		Linolenic acid	-	-	-	10	-	-	-	-
		Other component	5	5	3	4	4	5	3	3
Composition of lubricating oil composition (unit: mass%)	Vegetable oil (A)	Refined olive oil	94.55	94.65	-	-	-	93.03	-	-
		High-oleic sunflower oil	-	-	94.55	-	-	-	95.75	97.95
	Vegetable oil (A')	Rapeseed white squeezed oil	-	-	-	94.55	-	-	-	-
		Salad oil	-	-	-	-	94.55	-	-	-
	ZnDTP (B)		0.70	0.70	0.70	0.70	0.70	0.70	-	0.7
	Amine-based antioxidant (C)	Dioctyldipheny lamine	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.50
		p-t-Octylphenyl-1-naphthylamine	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.50
	Phosphrous-free phenol-based antioxidant (D)	Benzenepropan oic acid 3,5-bis(1,1-dimethylethyl)-4-hydroxyalkyl ester	-	-	-	-	-	2.00	-	-
	ZnDTC (E)		0.10	-	0.10	0.10	0.10	0.10	-	0.10
	Phosphorus-containing phenol-based antioxidant (F)	Diethyl 3,5-di-tert-butyl-4-hydroxybenzyl phosphonate	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Other component	Carboxylic acid amide	-	-	-	-	-	-	0.10	0.10
		Alkenylsuccini c acid	-	-	-	-	-	0.02	-	-

(continued)

			Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
		polyhydric alcohol ester								
		Dinonylnaphth alenesulfonic acid barium salt 50%	0.50	0.50	0.50	0.50	0.50	-	-	-
		Silicone-based anti-foaming agent	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Total		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Physical property of lubricatin g oil composit ion	40°C kinematic viscosity mm^2/s		42.82	42.79	43.34	35.80	30.94	42.81	43.10	43.05
Evaluatio n result	ISOT test (120°C×24 0 hr)	40°C kinematic viscosity mm^2/s	85.23	77.77	76.23	Unmeasurable	Unmeasurable	86.67	Unmeasurable	48.61
		Increase rate of 40°C kinematic viscosity %	199	182	176	-	-	202	-	113
		Acid value mgKOH/g	8.89	11.12	5.00	Unmeasurable	Unmeasurable	7.23	Unmeasurable	4.15
		Millipore value mg/100 mL	0.3	2.9	3.9	Unmeasurable	Unmeasurable	78.0	Unmeasurable	4.5
	Panel coking test (270°C)	Carbon adhesion amount mg	35	36	33	88	55	112	45	288

[0178] The following is found from the results shown in Table 1.

[0179] It is found that the lubricating oil compositions of Examples 1 to 3 are each a lubricating oil composition excellent in oxidation stability because the compositions are each low in kinematic viscosity increase rate, acid value, and millipore value after the ISOT test (120°C×240 hours), and in carbon adhesion amount after the panel coking test (270°C).

[0180] In contrast, it is found that the lubricating oil compositions of Comparative Examples 1 to 5 are each a lubricating oil composition poor in oxidation stability because at least one of the kinematic viscosity increase rate, acid value, or millipore value of each of the compositions after the ISOT test (120°C×240 hours), or the carbon adhesion amount thereof after the panel coking test (270°C) is high or unmeasurable.

Claims

1. A lubricating oil composition, comprising:

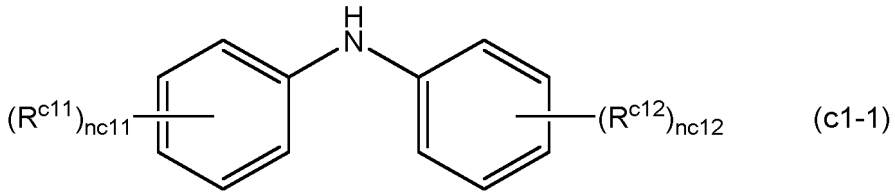
a vegetable oil (A);
a zinc dithiophosphate (B); and
an amine-based antioxidant (C),
wherein a total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to a total amount of the constituent fatty acids in the vegetable oil (A),
wherein a content of the amine-based antioxidant (C) is 2.00 mass% or more with respect to a total amount of the lubricating oil composition, and
wherein when the lubricating oil composition further comprises a phosphorus-free phenol-based antioxidant (D), a content of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

2. The lubricating oil composition according to claim 1, wherein a content of oleic acid among the constituent fatty acids of the vegetable oil (A) is 65 mass% or more with respect to the total amount of the constituent fatty acids in the vegetable oil (A).

3. The lubricating oil composition according to claim 1 or 2, wherein a content of the zinc dithiophosphate (B) is 0.10 mass% or more with respect to the total amount of the lubricating oil composition.

4. The lubricating oil composition according to any one of claims 1 to 3, wherein the amine-based antioxidant (C) comprises a diphenylamine-based antioxidant (C1) and a naphthylamine-based antioxidant (C2).

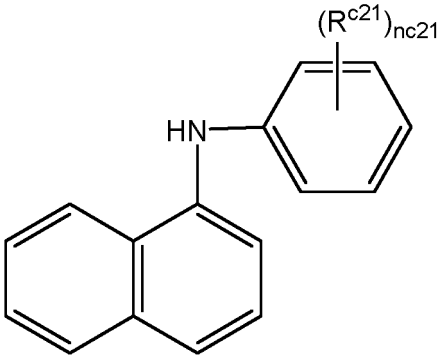
5. The lubricating oil composition according to claim 4, wherein the diphenylamine-based antioxidant (C1) is a compound represented by the following general formula (c1-1):



(c1-1)

wherein in the general formula (c1-1), R^{c11} and R^{c12} each independently represent an alkyl group having 1 to 30 carbon atoms, and nc11 and nc12 each independently represent an integer of from 1 to 5.

6. The lubricating oil composition according to claim 4 or 5, wherein the naphthylamine-based antioxidant (C2) is a compound represented by the following general formula (c2-1):



(c2-1)

wherein in the general formula (c2-1), R^{c21} represents an alkyl group having 1 to 30 carbon atoms, and nc21 represents an integer of from 1 to 5.

7. The lubricating oil composition according to any one of claims 1 to 6, further comprising a zinc dithiocarbamate (E).

8. The lubricating oil composition according to any one of claims 1 to 7, further comprising a phosphorus-comprising phenol-based antioxidant (F).

9. The lubricating oil composition according to any one of claims 1 to 8, further comprising one or more kinds selected from the group consisting of: a metal deactivator; a rust inhibitor; and an antifoaming agent.

10. The lubricating oil composition according to any one of claims 1 to 9, wherein the lubricating oil composition is used as an industrial equipment oil.

11. A method of using the lubricating oil composition of any one of claims 1 to 9, comprising using the lubricating oil composition as an industrial equipment oil.

12. A method of producing a lubricating oil composition, comprising a step of mixing a vegetable oil (A), a zinc dithiophosphate (B), and an amine-based antioxidant (C) to prepare the lubricating oil composition,

wherein a total content of linoleic acid and linolenic acid among constituent fatty acids of the vegetable oil (A) is less than 20 mass% with respect to a total amount of the constituent fatty acids in the vegetable oil (A),
wherein a blending amount of the amine-based antioxidant (C) is 2.00 mass% or more with respect to a total amount of the lubricating oil composition, and
wherein when the lubricating oil composition is further blended with a phosphorus-free phenol-based antioxidant (D), a blending amount of the phosphorus-free phenol-based antioxidant (D) is less than 2.00 mass% with respect to the total amount of the lubricating oil composition.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/023464

A. CLASSIFICATION OF SUBJECT MATTER

C10M 169/04(2006.01)i; *C10M 101/04*(2006.01)n; *C10M 129/10*(2006.01)n; *C10M 133/12*(2006.01)n; *C10M 135/18*(2006.01)n; *C10M 137/10*(2006.01)n; *C10N 10/04*(2006.01)n; *C10N 30/08*(2006.01)n; *C10N 40/00*(2006.01)n; *C10N 40/04*(2006.01)n; *C10N 40/08*(2006.01)n; *C10N 40/12*(2006.01)n; *C10N 40/30*(2006.01)n

FI: C10M169/04; C10M137/10 A; C10M133/12; C10M129/10; C10M135/18; C10N40:12; C10N40:00 A; C10N40:08; C10N40:30; C10N40:04; C10N30:08; C10N10:04; C10M101/04

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; C10M101/04; C10M129/10; C10M133/12; C10M135/18; C10M137/10; C10N10/04; C10N30/08; C10N40/00; C10N40/04; C10N40/08; C10N40/12; C10N40/30

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)

JSTPlus/JMEDPlus/JST7580 (JDreamIII)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 10-231494 A (NIPPON STEEL CORPORATION) 02 September 1998 (1998-09-02) claims, paragraphs [0015], [0024], [0065]-[0068], [0085]-[0102], example 3, etc.	1, 3, 9-12
Y		2, 4-8
X	JP 2015-189929 A (IDEMITSU KOSAN COMPANY, LIMITED) 02 November 2015 (2015-11-02) claims, paragraphs [0011], [0036]-[0046], examples 9, 12, etc.	1, 3, 9-12
Y		2, 4-8
X	WO 2011/125679 A1 (IDEMITSU KOSAN COMPANY, LIMITED) 13 October 2011 (2011-10-13) claims, paragraphs [0009]-[0010], [0020]-[0024], [0029]-[0039], examples, etc.	1-3, 9-12
Y		4-8

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

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Date of the actual completion of the international search	Date of mailing of the international search report
04 August 2023	**15 August 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/JP2023/023464

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	JP 2019-35053 A (UACJ CORPORATION) 07 March 2019 (2019-03-07) paragraph [0026]	2
Y	JP 2001-181674 A (NOF CORPORATION) 03 July 2001 (2001-07-03) paragraphs [0010]-[0011]	2
Y	WO 2017/168868 A1 (IDEMITSU KOSAN COMPANY, LIMITED) 05 October 2017 (2017-10-05) claims, paragraphs [0058]-[0060], [0066], [0121], table 4, examples 7-8, etc.	4-8
A	JP 2008-531826 A (CHEMTURA CORPORATION) 14 August 2008 (2008-08-14) claims, examples, etc.	1-12
A	CN 112500909 A (SHANGHAI INSTITUTE OF TECHNOLOGY) 16 March 2021 (2021-03-16) claims, examples, etc.	1-12
A	JP 2009-144045 A (NIPPON OIL CORPORATION) 02 July 2009 (2009-07-02) claims, examples, etc.	1-12
A	JP 2009-161664 A (NIPPON OIL CORPORATION) 23 July 2009 (2009-07-23) claims, examples, etc.	1-12

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/023464

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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JP 2015-189929 A	02 November 2015	(Family: none)	
WO 2011/125679 A1	13 October 2011	US 2013/0017984 A1 claims, paragraphs [0023]-[0025], [0037]-[0045], [0051]-[0072], examples, etc. EP 2554646 A1 CN 102812114 A	
JP 2019-35053 A	07 March 2019	(Family: none)	
JP 2001-181674 A	03 July 2001	(Family: none)	
WO 2017/168868 A1	05 October 2017	US 2019/0106645 A1 claims, paragraphs [0114]-[0121], [0134], [0256]-[0259], table 4, examples 7-8, etc. EP 3438234 A1 CN 108884412 A	
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CN 112500909 A	16 March 2021	(Family: none)	
JP 2009-144045 A	02 July 2009	(Family: none)	
JP 2009-161664 A	23 July 2009	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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- JP 8311466 A **[0004]**