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

(11) EP 3 279 292 A1

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

(43) Date of publication:
07.02.2018 Bulletin 2018/06

(21) Application number: **16772852.6**

(22) Date of filing: **29.03.2016**

(51) Int Cl.:
C10M 141/12 (2006.01)
C10M 101/02 (2006.01)
C10M 107/02 (2006.01)
C10M 129/68 (2006.01)
C10M 129/76 (2006.01)
C10M 133/04 (2006.01)
C10M 135/18 (2006.01)
C10M 137/10 (2006.01)
C10M 139/00 (2006.01)
C10M 145/14 (2006.01)
C10N 10/04 (2006.01)
C10N 10/12 (2006.01)
C10N 30/00 (2006.01)
C10N 30/06 (2006.01)
C10N 40/25 (2006.01)

(86) International application number:
PCT/JP2016/060168

(87) International publication number:
WO 2016/158971 (06.10.2016 Gazette 2016/40)

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

(30) Priority: **31.03.2015 JP 2015074366**

(71) Applicant: **Idemitsu Kosan Co., Ltd**
Tokyo 100-8321 (JP)

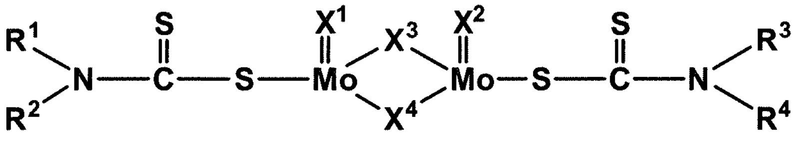
(72) Inventors:
- **NAKAYA, Ikuko**
  Ichihara-shi
  Chiba 299-0107 (JP)
- **TAMURA, Kazushi**
  Ichihara-shi
  Chiba 299-0107 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) LUBRICANT OIL COMPOSITION AND INTERNAL-COMBUSTION-ENGINE FRICTION REDUCTION METHOD

(57) A lubricating oil composition which exhibits an excellent friction-reducing effect and excellent fuel consumption reducing properties is provided.

The lubricating oil composition includes a lubricating base oil (A), a molybdenum compound (B), and an ashless friction modifier (C), wherein the lubricating oil composition includes a binuclear organic molybdenum compound represented by the following general formula (I) as the molybdenum compound (B), with the content of the binuclear organic molybdenum compound as converted into molybdenum atoms being 0.030 mass% or more and 0.140 mass% or less based on the total amount of the lubricating oil composition; and an ester-based ashless friction modifier (C1) and/or an amine-based ashless friction modifier (C2) as the ashless friction modifier (C), with the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) being more than 0.1 mass% and 1.8 mass% or less based on the total amount of the lubricating oil composition:



(I)

in the general formula (I), R^1 to R^4 each represents a hydrocarbon group having 4 to 22 carbon atoms, R^1 to R^4 may be the same as or different from each other, and X^1 to X^4 each represents a sulfur atom or an oxygen atom.

EP 3 279 292 A1

Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to a lubricating oil composition and a method for reducing friction of an internal combustion engine.

Background Art

[0002] In recent years, following the strengthening of environmental regulations, high fuel consumption reducing properties have been required for engine oils. For this reason, efforts have been made regarding blending a molybdenum compound such as molybdenum dithiocarbamate (MoDTC) into a lubricating oil composition, thereby reducing a metal-to-metal friction coefficient.

[0003] The molybdenum compound such as MoDTC exhibits a friction-reducing effect in a relatively high temperature region of 80°C or higher. Examples of the lubricating oil composition having a molybdenum compound blended therein include those disclosed in PTL 1.

[0004] Meanwhile, ashless friction modifiers such as an ester-based friction modifier and an amine-based friction modifier are also used so as to reduce friction (for example, PTL 2).

[0005] These ashless friction modifiers have excellent friction-reducing effects in a relatively low temperature region of lower than 80°C.

[0006] Taking into consideration the friction-reducing characteristics of a molybdenum compound in a high-temperature region and the friction-reducing characteristics of an ashless friction modifier in a low-temperature region, it can be expected that a friction-reducing effect is exhibited in a wide temperature region by using a molybdenum compound in combination with an ashless friction modifier.

Citation List

Patent Literature

[0007]

PTL 1: JP 2015-010177 A
PTL 2: WO 2011/062282 A

Summary of Invention

Technical Problem

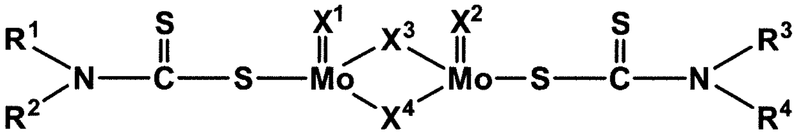
[0008] However, in a case of using a molybdenum compound in combination with an ashless friction modifier, there was involved such a problem that the ashless friction modifier inhibits a friction-reducing effect of the molybdenum compound, and consequently, impairs fuel consumption reducing properties.

[0009] It is an object of the present invention to provide a lubricating oil composition which exhibits an excellent friction-reducing effect and excellent fuel consumption reducing properties.

Solution to Problem

[0010] In order to solve the aforementioned problem, an embodiment of the present invention provides a lubricating oil composition including a lubricating base oil (A), a molybdenum compound (B), and an ashless friction modifier (C), wherein the lubricating oil composition includes a binuclear organic molybdenum compound represented by the following general formula (I) as the molybdenum compound (B), with the content of the binuclear organic molybdenum compound as converted into molybdenum atoms being 0.030 mass% or more and 0.140 mass% or less based on the total amount of the lubricating oil composition; and

an ester-based ashless friction modifier (C1) and/or an amine-based ashless friction modifier (C2) as the ashless friction modifier (C), with the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) being more than 0.1 mass% and 1.8 mass% or less based on the total amount of the lubricating oil composition:


(I)

in the general formula (I), R^1 to R^4 each represents a hydrocarbon group having 4 to 22 carbon atoms, R^1 to R^4 may be the same as or different from each other, and X^1 to X^4 each represents a sulfur atom or an oxygen atom. Advantageous Effect of Invention

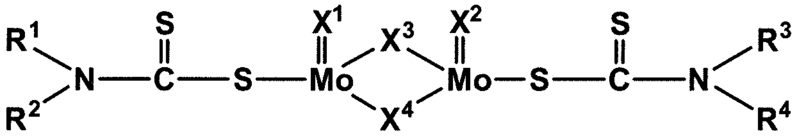
[0011] Since the lubricating oil composition of the present invention makes it possible to use the molybdenum compound in combination with an ashless friction modifier without inhibiting the friction-reducing effect of a molybdenum compound, the lubricating oil composition exhibits an excellent friction-reducing effect and can enhance fuel consumption reducing properties.

Description of Embodiments

[0012] Hereinafter, an embodiment of the present invention will be described.

[Lubricating Oil Composition]

[0013] The lubricating oil composition of the present embodiment is a lubricating oil composition including a lubricating base oil (A), a molybdenum compound (B), and an ashless friction modifier (C),
wherein the lubricating oil composition includes a binuclear organic molybdenum compound represented by the following general formula (I) as the molybdenum compound (B), with the content of the binuclear organic molybdenum compound as converted into molybdenum atoms being 0.030 mass% or more and 0.140 mass% or less based on the total amount of the lubricating oil composition; and
an ester-based ashless friction modifier (C1) and/or an amine-based ashless friction modifier (C2) as the ashless friction modifier (C), with the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) being more than 0.1 mass% and 1.8 mass% or less based on the total amount of the lubricating oil composition:


(I)

in the general formula (I), R^1 to R^4 each represents a hydrocarbon group having 4 to 22 carbon atoms, R^1 to R^4 may be the same as or different from each other, and X^1 to X^4 each represents a sulfur atom or an oxygen atom.

<(A) Lubricating Base Oil>

[0014] The lubricating oil composition of the present embodiment includes a lubricating base oil (A). Examples of the lubricating base oil as the component (A) include a mineral oil and/or a synthetic oil.

[0015] Examples of the mineral oil include a paraffin-based mineral oil, an intermediate-based mineral oil, and a naphthene-based mineral oil, obtained by a usual refining method such as solvent refining and hydrogenation refining; and wax-isomerized oils produced by isomerizing a wax such as a wax (a gas-to-liquid wax) produced by a Fischer-Tropsch process or the like, and a mineral oil-based wax.

[0016] Examples of the synthetic oil include a hydrocarbon-based synthetic oil and an ether-based synthetic oil. Examples of the hydrocarbon-based synthetic oil include an α-olefin oligomer such as polybutene, polyisobutylene, a 1-octene oligomer, a 1-decene oligomer, and an ethylene-propylene copolymer, or a hydride thereof; an alkylbenzene; and an alkylnaphthalene. Examples of the ether-based synthetic oil include polyoxyalkylene glycol and polyphenyl ether.

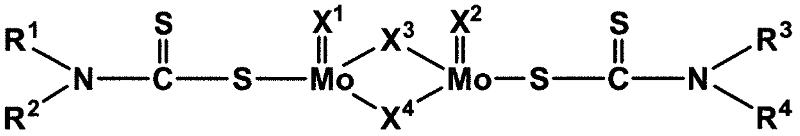
[0017] Although the lubricating base oil (A) may be of a single system using one of the aforementioned mineral oils and synthetic oils, it may also be of a mixed system, for example, a mixture of two or more mineral oils, a mixture of two or more synthetic oils, or a mixture of each one or each two or more of mineral oils and synthetic oils.

[0018] In particular, it is preferable to use one or more selected from mineral oils or synthetic oils classified into Group 3 and Group 4 in the base oil classification of the American Petroleum Institute as the lubricating base oil (A).

[0019] The content of the lubricating base oil (A) is preferably 60 mass% or more, more preferably 65 mass% or more and 95 mass% or less, and still more preferably 70 mass% or more and 85 mass% or less, based on the total amount of the lubricating oil composition.

<Molybdenum Compound (B)>

[0020] The lubricating oil composition of the present embodiment includes a molybdenum compound (B). Further, the lubricating oil composition of the present embodiment includes a binuclear organic molybdenum compound represented by the following general formula (I) as the molybdenum compound of the component (B), and the content of the binuclear organic molybdenum compound as converted into molybdenum atoms is 0.030 mass% or more and 0.140 mass% or less based on the total amount of the lubricating oil composition.



(I)

[0021] In the general formula (I), R^1 to R^4 each represents a hydrocarbon group having 4 to 22 carbon atoms, and R^1 to R^4 may be the same as or different from each other. When the number of carbon atoms is 3 or less, the oil solubility becomes poor, whereas when the number of carbon atoms is 23 or more, the melting point becomes high, the handling becomes deteriorated, and the friction-reducing ability becomes low. From the viewpoints, the number of carbon atoms is preferably 4 to 18, and more preferably 8 to 13.

[0022] Examples of the hydrocarbon group of R^1 to R^4 include an alkyl group, an alkenyl group, an alkylaryl group, a cycloalkyl group, and a cycloalkenyl group. A branched or linear alkyl group or alkenyl group is preferable, and a branched or linear alkyl group is more preferable. Examples of the branched or linear alkyl group include an n-octyl group, a 2-ethylhexyl group, an isononyl group, an n-decyl group, an isodecyl group, a dodecyl group, a tridecyl group, and an isotridecyl group.

[0023] Furthermore, from the viewpoints of solubility in the base oil, storage stability, and friction-reducing ability, in the binuclear organic molybdenum compound represented by the general formula (I), it is preferable that R^1 and R^2 are the same alkyl group, R^3 and R^4 are the same alkyl group, and the alkyl groups of R^1 and R^2 and the alkyl groups of R^3 and R^4 are different from each other.

[0024] Moreover, in the general formula (1), X^1 to X^4 each represents a sulfur atom or an oxygen atom, and X^1 to X^4 may be the same as or different from each other. The ratio of the sulfur atoms to the oxygen atoms is preferably 1/3 to 3/1, and more preferably 1.5/2.5 to 3/1 as converted into sulfur atoms/oxygen atoms. When the ratio falls within the range, good performance is obtained in view of corrosion resistance and solubility in a lubricating base oil. In addition, all of X^1 to X^4 may also be a sulfur atom or an oxygen atom.

[0025] In the lubricating oil composition of the present embodiment, the content of the binuclear organic molybdenum compound as converted into molybdenum atoms needs to be 0.030 mass% or more and 0.140 mass% or less based on the total amount of the lubricating oil composition.

[0026] In a case where the content of the binuclear organic molybdenum compound as converted into molybdenum atoms is less than 0.030 mass%, the friction-reducing effect in a high-temperature region cannot be enhanced, and thus, fuel consumption reducing properties cannot be satisfied. Further, in a case where the content of the binuclear organic molybdenum compound as converted into molybdenum atoms is more than 0.140 mass%, cleanness is deteriorated.

[0027] The content of the binuclear organic molybdenum compound as converted into molybdenum atoms is preferably 0.050 to 0.120 mass%, and more preferably 0.060 to 0.100 mass%, based on the total amount of the lubricating oil composition.

[0028] In addition, the lubricating oil composition of the present embodiment may further contain a mononuclear organic molybdenum compound and/or a trinuclear organic molybdenum compound as the molybdenum compound.

<Ashless Friction Modifier (C)>

[0029] The lubricating oil composition of the present embodiment includes an ashless friction modifier (C). Further, the lubricating oil composition of the present embodiment includes an ester-based ashless friction modifier (C1) and/or an amine-based ashless friction modifier (C2) as the ashless friction modifier of the component (C), and the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) is more than 0.1 mass% and 1.8 mass% or less based on the total amount of the lubricating oil composition.

[0030] Moreover, in the present embodiment, in a case where the ester-based ashless friction modifier (C1) is not included and only the amine-based ashless friction modifier (C2) is included, the content of the amine-based ashless friction modifier (C2) falls within the range. Further, in the present embodiment, in a case where the amine-based ashless friction modifier (C2) is not included and only the ester-based ashless friction modifier (C1) is included, the content of the ester-based ashless friction modifier (C1) falls within the range. In addition, in various suitable embodiments which will be described later, in a case where only any one of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) is included, the one ashless friction modifier satisfies various suitable embodiments.

[0031] In a case where the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) is 0.1 mass% or less based on the total amount of the lubricating oil composition, it is not possible to impart a friction-reducing effect based on the component (C1) and/or the component (C2). Further, in a case where the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) is more than 1.8 mass% based on the total amount of the lubricating oil composition, a friction-reducing effect based on the molybdenum compound (B) is inhibited, and in turn, the friction coefficient increases.

[0032] Meanwhile, by allowing the lubricating oil composition of the present embodiment to use the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2) as the ashless friction modifier of the component (C), and allowing the total content of these components to fall within the range, the lubricating oil composition can enhance the friction-reducing effect, and thus enhance the fuel consumption reducing properties.

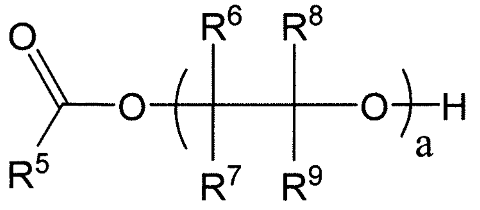
[0033] The total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) is preferably 0.2 mass% or more and 1.7 mass% or less, and more preferably 0.4 mass% or more and 1.6 mass% or less, based on the total amount of the lubricating oil composition.

Ester-Based Ashless Friction Modifier (C1)

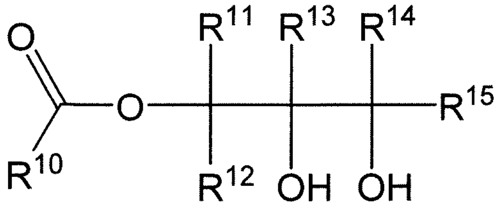
[0034] Various ester compounds can be used as the ester-based ashless friction modifier of the component (C1), in which an ester compound having one or more hydroxyl groups in a molecule thereof is preferable, and an ester compound having two or more hydroxyl groups in a molecule thereof is more preferable.

[0035] In addition, the ester compound having one or more hydroxyl groups in a molecule thereof preferably has 2 to 24 carbon atoms, more preferably has 10 to 24 carbon atoms, and still more preferably has 16 to 22 carbon atoms.

[0036] Examples of the ester compound having one or more hydroxyl groups in a molecule thereof include an ester compound having one hydroxyl group in a molecule thereof as in the following general formula (II) and a compound having two hydroxyl groups in a molecule thereof as in the following general formula (III). Among these, a compound represented by the general formula (III) is suitable.



(II)



(III)

[0037] In the general formulae (II) and (III), R^5 and R^{10} are each a hydrocarbon group having 1 to 32 carbon atoms.

[0038] The number of carbon atoms of the hydrocarbon group of R^5 and R^{10} is preferably 8 to 32, more preferably 12 to 24, and still more preferably 16 to 20.

[0039] Examples of the hydrocarbon group of R^5 and R^{10} include an alkyl group, an alkenyl group, an alkylaryl group, a cycloalkyl group, and a cycloalkenyl group. Among these, an alkyl group or an alkenyl group is preferable, with an alkenyl group being more preferable.

[0040] Examples of the alkyl group in R^5 and R^{10} 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 eicosyl group, a heneicosyl group, a docosyl group, a tricosyl group, and a tetracosyl group. These may be linear, branched, or cyclic.

[0041] Furthermore, examples of the alkenyl group in R^5 and R^{10} include a vinyl group, a propenyl group, a butenyl group, a pentenyl group, a hexenyl group, a heptenyl group, an octenyl group, a nonenyl group, a decenyl group, an undecenyl group, a dodecenyl group, a tridecenyl group, a tetradecenyl group, a pentadecenyl group, a hexadecenyl group, a heptadecenyl group, an octadecenyl group, a nonadecenyl group, an eicosenyl group, a heneicosenyl group, a docosenyl group, a tricosenyl group, and a tetracosenyl group. These may be linear, branched, or cyclic, and the position of the double bond is arbitrary.

[0042] R^6 to R^9 and R^{11} to R^{15} are each a hydrogen atom or a hydrocarbon group having 1 to 18 carbon atoms, and they may be the same as or different from each other.

[0043] In the general formula (II), it is preferable that all of R^6 to R^9 are a hydrogen atom, or all of R^6 to R^8 are a hydrogen atom, and R^9 is a hydrocarbon group. Further, in the general formula (III), it is preferable that all of R^{11} to R^{15} are a hydrogen atom.

[0044] In a case where the compound represented by the general formula (II) is used as the ester-based ashless friction modifier (C1), a single kind of the compound in which all of R^5's to R^9's are all the same may be used, or a mixture of two or more kinds of the compounds in which some of R^5's to R^9's are different (for example, those in which the number of carbon atoms or the presence or absence of a double bond of R^5's is different) may be used. Similarly, in a case where the compound represented by the general formula (III) is used as the ester-based ashless friction modifier (C1), a single kind of the compound in which all of R^{10}'s to R^{15}'s are all the same may be used, or a mixture of two or more kinds of the compounds in which R^{10}'s to R^{15}'s are different (for example, those in which the number of carbon atoms or the presence or absence of a double bond of R^{10}'s is different, or R^{11}'s to R^{15}'s are different) may be used.

[0045] In a case where R^6 to R^9 and R^{11} to R^{15} are a hydrocarbon group, the hydrocarbon group may be either saturated or unsaturated, may be either aliphatic or aromatic, and may be linear, branched, or cyclic.

[0046] Furthermore, in the general formula (II), "a" represents an integer of 1 to 20, and is preferably 1 to 12, and more preferably 1 to 10.

[0047] The compound represented by the general formula (II) is, for example, a compound obtained through a reaction of a fatty acid and an alkylene oxide.

[0048] Here, examples of the fatty acid for obtaining the compound represented by the general formula (II) include lauric acid, myristic acid, palmitic acid, oleic acid, tallow acid, and coconut fatty acid. Examples of the alkylene oxide include alkylene oxides having 2 to 12 carbon atoms, and specific examples thereof include ethylene oxide, propylene oxide, butylene oxide, hexylene oxide, octylene oxide, decylene oxide, and dodecylene oxide.

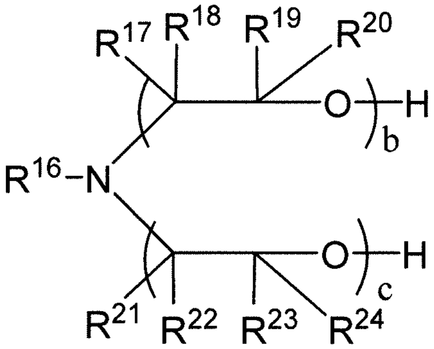
[0049] Examples of the compound of the general formula (II) include polyoxyethylene monolaurate, polyoxyethylene monostearate, and polyoxyethylene monooleate.

[0050] Examples of the compound represented by the general formula (III) include glycerin fatty acid monoesters such as glycerin monolaurate, glycerin monostearate, glycerin monomyristate, and glycerin monooleate. Among these, glycerin monooleate is suitable.

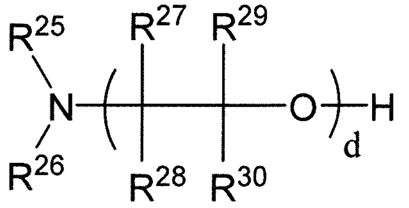
Amine-Based Ashless Friction Modifier (C2)

[0051] As the amine-based ashless friction modifier (C2), an aliphatic amine-based compound is suitable, and an aliphatic amine-based compound having one or more hydroxyl groups in a molecule thereof is more suitable. Further, the amine-based ashless friction modifier (C2) may be any one of primary, secondary, and tertiary amines, with a tertiary amine being suitable.

[0052] Examples of the amine-based ashless friction modifier (C2) which is a tertiary amine, as the aliphatic amine-based compound having one or more hydroxyl groups in a molecule thereof, include compounds represented by the following general formulae (IV) and (V), with a compound represented by the general formula (IV) being suitable.



(IV)



(V)

[0053] In the general formulae (IV) and (V), R^{16}, R^{25}, and R^{26} are each a hydrocarbon group having 1 to 32 carbon atoms, and R^{25} and R^{26} may be the same as or different from each other.

[0054] The number of carbon atoms of the hydrocarbon group of R^{16}, R^{25}, and R^{26} is preferably 8 to 32, more preferably 10 to 24, and still more preferably 12 to 20.

[0055] Examples of the hydrocarbon group of R^{16}, R^{25}, and R^{26} include an alkyl group, an alkenyl group, an alkylaryl group, a cycloalkyl group, and a cycloalkenyl group. Among these, an alkyl group or an alkenyl group is preferable.

[0056] Examples of the alkyl group of R^{16}, R^{25}, and R^{26} 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 eicosyl group, a heneicosyl group, a docosyl group, a tricosyl group, and a tetracosyl group. These may be linear, branched, or cyclic.

[0057] Furthermore, examples of the alkenyl group represented by R^{16}, R^{25}, and R^{26} include a vinyl group, a propenyl group, a butenyl group, a pentenyl group, a hexenyl group, a heptenyl group, an octenyl group, a nonenyl group, a decenyl group, an undecenyl group, a dodecenyl group, a tridecenyl group, a tetradecenyl group, a pentadecenyl group, a hexadecenyl group, a heptadecenyl group, an octadecenyl group, a nonadecenyl group, an eicosenyl group, a heneicosenyl group, a docosenyl group, a tricosenyl group, and a tetracosenyl group. These may be linear, branched, or cyclic, and the position of the double bond is arbitrary.

[0058] R^{17} to R^{24} and R^{27} to R^{30} are each a hydrogen atom, a hydrocarbon group having 1 to 18 carbon atoms, or an oxygen-containing hydrocarbon group that contains an ether bond or an ester bond. These may be the same as or different from each other, and each is preferably a hydrogen atom or the hydrocarbon group.

[0059] The hydrocarbon group of R^{17} to R^{24} and R^{27} to R^{30} may be saturated or unsaturated, aliphatic or aromatic, and linear, branched or cyclic, and examples of the hydrocarbon group include aliphatic hydrocarbon groups such as an alkyl group and an alkenyl group, and aromatic hydrocarbon groups. More specific examples thereof include aliphatic hydrocarbon groups such as a methyl group, an ethyl group, a propyl group, a butyl group, a butenyl group, a hexyl group, a hexenyl group, an octyl group, an octenyl group, a 2-ethylhexyl group, a nonyl group, a decyl group, an undecyl group, a decenyl group, a dodecyl group, a dodecenyl group, a tridecyl group, a tetradecyl group, a tetradecenyl group, a pentadecyl group, a hexadecyl group, a hexadecenyl group, a heptadecyl group, an octadecyl group, an octadecenyl group, a stearyl group, an isostearyl group, an oleyl group, a linoleic group, a cyclopentyl group, a cyclohexyl group, a methylcyclohexyl group, an ethylcyclohexyl group, a propylcyclohexyl group, a dimethylcyclohexyl group, and a trimethylcyclohexyl group; and aromatic hydrocarbon groups such as a phenyl group, a methylphenyl group, an ethylphenyl group, a dimethylphenyl group, a propylphenyl group, a trimethylphenyl group, a butylphenyl group, and a naphthyl group.

[0060] The hydrocarbon group is preferably a hydrocarbon group having 1 to 18 carbon atoms, more preferably a hydrocarbon group having 1 to 12 carbon atoms, still more preferably a hydrocarbon group having 1 to 4 carbon atoms, and most preferably a hydrocarbon group having 2 carbon atoms.

[0061] The oxygen-containing hydrocarbon group that contains an ether bond or an ester bond is preferably the group having 1 to 18 carbon atoms, and examples thereof include a methoxymethyl group, an ethoxymethyl group, a propoxymethyl group, an isopropoxymethyl group, a n-butoxymethyl group, a t-butoxymethyl group, a hexyloxymethyl group, an octyloxymethyl group, a 2-ethyl-hexyloxymethyl group, a decyloxymethyl group, a dodecyloxymethyl group, a 2-butyloctyloxymethyl group, a tetradecyloxymethyl group, a hexadecyloxymethyl group, a 2-hexyldodecyloxymethyl group, an allyloxymethyl group, a phenoxy group, a benzyloxy group, a methoxyethyl group, a methoxypropyl group, a 1,1-bismethoxypropyl group, a 1,2-bismethoxypropyl group, an ethoxypropyl group, a (2-methoxyethoxy)propyl group, a (1-methyl-2-methoxy)propyl group, an acetyloxymethyl group, a propanoyloxymethyl group, a butanoyloxymethyl group, a hexanoyloxymethyl group, an octanoyloxymethyl group, a 2-ethylhexanoyloxymethyl group, a decanoyloxymethyl group, a dodecanoyloxymethyl group, a 2-butyloctanoyloxymethyl group, a tetradecanoyloxymethyl group, a hexadecanoyloxymethyl group, a 2-hexyldodecanoyloxymethyl group, and a benzoyloxymethyl group.

[0062] Furthermore, b to d each represents an integer of 0 to 20.

[0063] b + c is preferably 1 to 20, more preferably 1 to 10, still more preferably 1 to 4, and most preferably 2.

[0064] In the general formula (IV), it is preferable that all of R^{17} to R^{24} are a hydrogen atom. Further, in the general formula (V), it is preferable that all of R^{27} to R^{30} are a hydrogen atom.

[0065] In a case where the aliphatic amine compound of the general formula (IV) is used as the amine-based ashless friction modifier (C2), the aliphatic amine compounds in which all of R^{16}'s are all the same may be used, or a mixture of the aliphatic amine compounds in which R^{16}'s are different (for example, those in which the number of carbon atoms or the presence or absence of a double bond is different) as for naturally derived hydrocarbon groups such as beef tallow may be used. Similarly, in the case where the aliphatic amine compound of the general formula (V) is used as the amine-based ashless friction modifier (C2), the aliphatic amine compounds in which R^{25}'s and R^{26}'s are all the same may be used, or a mixture of the aliphatic amine compounds in which R^{25}'s and R^{26}'s are different (for example, those in which the number of carbon atoms or the presence or absence of a double bond is different) may be used.

[0066] Specific examples of the compounds of the general formula (IV) include amine compounds having one 2-hydroxyalkyl group, for example, a hydroxyethyl group, such as octyl ethanolamine, decyl ethanolamine, dodecyl ethanolamine, tetradecyl ethanolamine, hexadecyl ethanolamine, stearyl ethanolamine, oleyl ethanolamine, coconut oil ethanolamine, palm oil ethanolamine, rapeseed oil ethanolamine, and beef tallow ethanolamine; amine compounds having two 2-hydroxyalkyl groups, such as octyl diethanolamine, decyl diethanolamine, dodecyl diethanolamine, tetradecyl diethanolamine, hexadecyl diethanolamine, stearyl diethanolamine, oleyl diethanolamine, coconut oil diethanolamine, palm oil diethanolamine, rapeseed oil diethanolamine, and beef tallow diethanolamine; and amine compounds having a polyalkylene oxide structure, such as polyoxyethylene octylamine, polyoxyethylene decylamine, polyoxyethylene dodecylamine, polyoxyethylene tetradecylamine, polyoxyethylene hexadecylamine, polyoxyethylene stearylamine, polyoxyethylene oleylamine, polyoxyethylene beef tallow amine, polyoxyethylene coconut oil amine, polyoxyethylene palm oil amine, polyoxyethylene laurylamine, polyoxyethylene stearylamine, polyoxyethylene oleylamine, and ethylene oxide-propylene oxide stearylamine.

[0067] Specific examples of the compounds of the general formula (V) include alkylamine compounds having one 2-hydroxyalkyl group, for example, hydroxyethyl groups such as N-methyl-octyl ethanolamine, N-methyl-decyl ethanolamine, N-methyl-dodecyl ethanolamine, N-methyl-tetradecyl ethanolamine, N-methyl-hexadecyl ethanolamine, N-methyl-stearyl ethanolamine, N-methyl-oleyl ethanolamine, N-methyl-coconut oil ethanolamine, N-methyl-palm oil ethanolamine, N-methyl-rapeseed oil ethanolamine, and N-methyl-beef tallow ethanolamine; and alkylamine compounds having a polyalkylene oxide structure, such as polyoxyethylene N-methyl-decylamine, polyoxyethylene N-methyl-dodecylamine, polyoxyethylene N-methyl-tetradecylamine, polyoxyethylene N-methyl-hexadecylamine, polyoxyethylene N-methyl-stearylamine, and polyoxyethylene N-methyl-oleylamine.

[0068] The lubricating oil composition of the present embodiment may include any one of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) as the ashless friction modifier of the component (C), but it is preferable that the ester-based ashless friction modifier (C1) is used in combination with the amine-based ashless friction modifier (C2).

[0069] By using the ester-based ashless friction modifier (C1) in combination with the amine-based ashless friction modifier (C2), a friction-reducing effect based on the molybdenum compound (B) can be more easily maintained. That is, by using the ester-based ashless friction modifier (C1) in combination with the amine-based ashless friction modifier (C2), it is possible to impart a friction-reducing effect based on three components of the molybdenum compound (B), the ester-based ashless friction modifier (C1), and the amine-based ashless friction modifier (C2), and thus, fuel consumption reducing properties can be more improved.

[0070] Furthermore, from the viewpoint that the effect can be easily exhibited by using the ester-based ashless friction modifier (C1) in combination with the amine-based ashless friction modifier (C2), the mass ratio of the content of the amine-based ashless friction modifier (C2) to the content of the ester-based ashless friction modifier (C1) [the content of the amine-based ashless friction modifier (C2)/the content of the ester-based ashless friction modifier (C1)] is preferably less than 1.00.

[0071] The ratio is more preferably 0.10 or more and 0.80 or less, and still more preferably 0.15 or more and 0.60 or less.

[0072] Moreover, the mass ratio of the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) to the content of the molybdenum compound (B) as converted into molybdenum atoms [(the content of the ester-based ashless friction modifier (C1) + the content of the amine-based ashless friction modifier (C2))/the content of the molybdenum compound (B) as converted into molybdenum atoms] is preferably 4.0 to 30.0, more preferably 5.0 to 25.0, and still more preferably 6.5 to 23.0.

[0073] The ashless friction modifier (C) may contain ashless type friction modifiers (other ashless type friction modifiers) other than the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2), within a range not impairing the effect of the lubricating oil composition of the present embodiment. Here, the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) based on the total amount of the ashless friction modifier (C), is preferably 80 mass% or more, more preferably 90 mass% or more, and still more preferably 100 mass%.

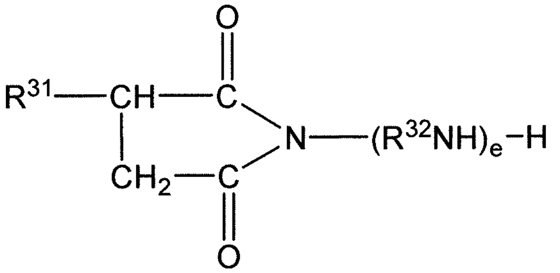
<Boratad succinimide (D)>

[0074] The lubricating oil composition of the present embodiment preferably further includes a boratad succinimide (D).

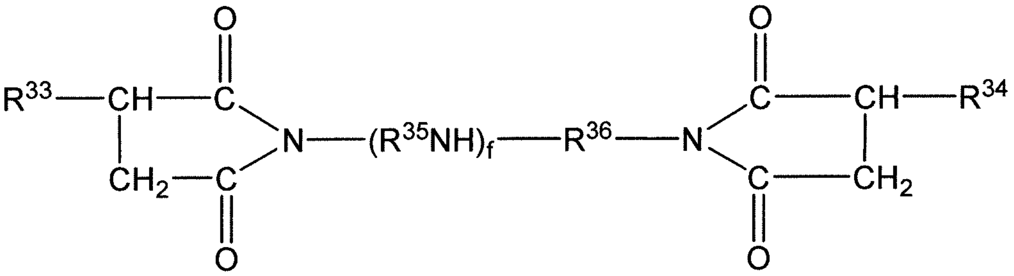
[0075] By using the molybdenum compound (B), and the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2), together with the boratad succinimide (D), a friction-reducing effect based on the molybdenum compound (B) can be more easily maintained, and as a result, the synergistic action with the molybdenum compound (B) and the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2) is easily exhibited, the friction-reducing effect is more enhanced, and the fuel consumption reducing properties can be enhanced.

[0076] Examples of the boratad succinimide of the component (D) include boronated products of alkenyl- or alkylsuccinic monoimide, or boronated products of alkenyl- or alkylsuccinic bisimide.

[0077] Examples of the alkenyl- or alkylsuccinic monoimide include a compound represented by the following general formula (VI). Further, examples of the alkenyl- or alkylsuccinic bisimide include a compound represented by the following general formula (VII).



(VI)



(VII)

[0078] In the general formulae (VI) and (VII), R^{31}, R^{33}, and R^{34} are each an alkenyl group or an alkyl group, and they each have a weight average molecular weight of preferably 500 to 3,000, and more preferably 1,000 to 3,000.

[0079] If the weight average molecular weight of R^{31}, R^{33}, and R^{34} is 500 or more, the solubility in a lubricating base oil can be enhanced. Further, if the weight average molecular weight is 3,000 or less, it is expected that the effect obtained by the present compound is appropriately exhibited. R^{33} and R^{34} may be the same as or different from each other.

[0080] R^{32}, R^{35}, and R^{36} are each an alkylene group having 2 to 5 carbon atoms, and R^{35} and R^{36} may be the same as or different from each other. "e" represents an integer of 1 to 10, and "f" represents 0 or an integer of 1 to 10.

[0081] Here, "e" is preferably 2 to 5, and more preferably 2 to 4. If "e" is 2 or more, it is expected that the effect obtained by the boratad succinimide is easily obtained. If "e" is 5 or less, the solubility in a lubricating base oil is more enhanced.

[0082] Furthermore, "f" is preferably 1 to 6, and more preferably 2 to 6. If "f" is 1 or more, it is expected that the effect obtained by the present compound is appropriately exhibited. If "f" is 6 or less, the solubility in a lubricating base oil is enhanced.

[0083] Examples of the alkenyl group include a polybutenyl group, a polyisobutenyl group, and an ethylene-propylene copolymer, and examples of the alkyl group include hydrogenated products thereof. Suitable examples of the alkenyl group include a polybutenyl group and a polyisobutenyl group. As the polybutenyl group, a mixture of 1-butene and isobutene or a product obtained by polymerization of high-purity isobutene is suitably used. Further, suitable representative examples of the alkyl group include hydrogenated products of a polybutenyl group or a polyisobutenyl group.

[0084] The boratad succinimide (D) can be obtained by, for example, reacting a polyolefin with maleic anhydride to obtain an alkenylsuccinic anhydride (x); reacting a polyamine with a boron compound to obtain an intermediate (y); and then reacting the alkenylsuccinic anhydride (x) with the intermediate (y), followed by imidization. The monoimide or the bisimide can be produced by changing the ratio of the alkenylsuccinic anhydride or the alkylsuccinic anhydride to the polyamine.

[0085] In addition, the boratad succinimide (D) can also be produced by treating an alkenyl- or alkylsuccinic monoimide or an alkenyl- or alkylsuccinic bisimide not containing boron with the boron compound.

[0086] As the olefin monomer that forms the polyolefin, one kind or a mixture of two or more kinds of α-olefins having 2 to 8 carbon atoms can be used, but a mixture of isobutene and 1-butene can be suitably used.

[0087] Meanwhile, examples of the polyamine include single diamines such as ethylenediamine, propylenediamine, butylendiamine, and pentylenediamine; polyalkylene polyamines such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, di(methylethylene)triamine, dibutylentriamine, tributylentetramine, and pentapentylenehexamine; and piperazine derivatives such as aminoethylpiperazine.

[0088] Examples of the boron compound include boric acid, borate, and a boric acid ester.

[0089] Examples of the boric acid include orthoboric acid, metaboric acid, and paraboric acid. Further, examples of the borate include ammonium borate, such as ammonium metaborate, ammonium tetraborate, ammonium pentaborate, and ammonium octaborate. Further, examples of the boric acid ester include monomethyl borate, dimethyl borate, trimethyl borate, monoethyl borate, diethyl borate, triethyl borate, monopropyl borate, dipropyl borate, tripropyl borate, monobutyl borate, dibutyl borate, and tributyl borate.

[0090] The ratio (B/N ratio) of the amount of boron atoms to the amount of nitrogen atoms, which are contained in the boratad succinimide (D), is preferably 0.6 or more, more preferably 0.7 or more, and still more preferably 0.8 or more, on a mass basis, in terms of friction reduction. Further, the B/N ratio is not particularly limited, but is preferably 2.0 or less, more preferably 1.5 or less, and still more preferably 1.3 or less.

[0091] From the viewpoint of friction reduction, the boratad succinimide (D) preferably includes a large amount of a three-coordinate boratad succinimide, and specifically, includes a three-coordinate boratad succinimide at a molar ratio of preferably 0.50 or more, more preferably 0.60 or more, and still more preferably 0.65 or more, relative to the total amount of three-coordinate boratad succinimide and four-coordinate boratad succinimide.

[0092] The ratio of three-coordinate boratad succinimide and the four-coordinate boratad succinimide can be measured by, for example, ^{11}B-NMR measurement as a $BF_3 \cdot OEt_2$ standard (0 ppm). In this ^{11}B-NMR measurement, the peaks of the three-coordinate boratad succinimide are shown at 5 to 25 ppm, and the peaks of the four-coordinate boratad succinimide are shown at -10 to 5 ppm, and thus, it is possible to calculate the ratio by calculating the integrated value of the respective peaks.

[0093] Moreover, in the lubricating oil composition of the present embodiment, the content of the boratad succinimide (D) as converted into boron atoms is preferably 0.050 mass% or less, more preferably 0.001 to 0.050 mass%, still more preferably 0.005 to 0.040 mass%, and even still more preferably 0.015 to 0.035 mass%, based on the total amount of the lubricating oil composition.

[0094] By allowing the content of the boratad succinimide (D) as converted into boron atoms to fall within the range, inhibition of a friction-reducing effect based on the molybdenum compound (B) can be suppressed, and as a result, the synergistic action with the molybdenum compound (B), and the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2) can be more exhibited, the friction-reducing effect can be more enhanced, and thus, the fuel consumption reducing properties can be more improved.

[0095] Furthermore, in the lubricating oil composition of the present embodiment, the mass ratio of the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) to the content of the boratad succinimide (D) as converted into boron atoms [the content of the boratad succinimide (D) as converted into boron atoms/(the content of the ester-based ashless friction modifier (C1) + the content of the amine-based ashless friction modifier (C2))] is preferably 0.011 or more, more preferably 0.013 or more and 0.100 or less, and still more preferably 0.015 or more and 0.070 or less.

[0096] By allowing the ratio to fall within the range, inhibition of a friction-reducing effect based on the molybdenum compound (B) can be more suppressed, and by the synergistic action with the molybdenum compound (B) and the ester-based ashless friction modifier (C1), the friction-reducing effect is more enhanced, and thus, the fuel consumption reducing properties can be more improved.

<Poly(meth)acrylate (E)>

[0097] It is preferable that the lubricating oil composition of the present embodiment further contains a poly(meth)acrylate (E) as a viscosity index improver. By containing the poly(meth)acrylate (E), the fuel consumption reducing properties can be more improved.

[0098] The monomer constituting the poly(meth)acrylate (E) is alkyl (meth)acrylate, and preferably alkyl (meth)acrylate with a linear alkyl group having 1 to 18 carbon atoms or a branched alkyl group having 3 to 34 carbon atoms.

[0099] Preferred examples of the monomer constituting the poly(meth)acrylate (E) include methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, butyl (meth)acrylate, pentyl (meth)acrylate, hexyl (meth)acrylate, hexyl (meth)acrylate, heptyl (meth)acrylate, octyl (meth)acrylate, nonyl (meth)acrylate, decyl (meth)acrylate, dodecyl (meth)acrylate, tetra(meth)acrylate, hexa(meth)acrylate, and octadecyl (meth)acrylate, and two or more kinds of these monomers may be used as a copolymer. The alkyl group of these monomers may be linear chained or branch chained.

[0100] Furthermore, examples of the alkyl (meth)acrylate with a branched alkyl group having 3 to 34 carbon atoms include isopropyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, 3,5,5-trimethylhexyl (meth)acrylate, 2-butyloctyl (meth)acrylate, 2-hexyldecyl (meth)acrylate, 2-octyldodecyl (meth)acrylate, 2-decyltetradecyl (meth)acrylate, 2-dodecyl hexadecyl (meth)acrylate, and 2-tetradecyloctadecyl (meth)acrylate.

[0101] The weight average molecular weight of the poly(meth)acrylate (E) is preferably 100,000 to 600,000, and more preferably 15,000 to 400,000.

[0102] Moreover, in the present embodiment, the "weight average molecular weight" refers to a molecular weight as converted into polystyrene, which is determined by a gel permeation chromatography (GPC) measurement.

[0103] The SSI of the poly(meth)acrylate (E) is preferably 50 or less, and more preferably 1 to 30. By allowing the weight average molecular weight to fall within the above range, the SSI can be adjusted to 30 or less.

[0104] Here, the SSI means a shear stability index, and represents an ability of resisting to decomposition of a poly(meth)acrylate. As the SSI is larger, the polymer is more unstable against shear and more easily decomposes.

$$SSI = \frac{Kv_0 - Kv_1}{Kv_0 - Kv_{oil}} \times 100$$

The SSI indicates a decrease in viscosity under shear derived from a polymer, and is calculated using the above calculation equation. In the equation, Kvo represents a value of kinematic viscosity at 100°C of a mixture obtained by adding a poly(meth)acrylate to a base oil. Kv_1 is a value of kinematic viscosity at 100°C measured after passing the mixture obtained by the addition of poly(meth)acrylate to the base oil through a high-shear Bosch diesel injector for 30 cycles in accordance with the procedures of ASTM D6278. Further, Kv_{oil} is a value of kinematic viscosity at 100°C of the base oil. In addition, as the base oil, a Group II base oil having a kinematic viscosity at 100°C of 5.35 mm^2/s and a viscosity index of 105 is used.

[0105] From the viewpoint of fuel consumption reducing properties, the content of the poly(meth)acrylate (E) is preferably 0.5 to 15 mass%, more preferably 1 to 10 mass%, and still more preferably 1 to 8 mass%, based on the total amount of the lubricating oil composition.

[0106] Here, the content of the poly(meth)acrylate means the content of only the resin fractions composed of poly(meth)acrylate, and is, for example, a content on a solid content basis which does not include the mass of a diluent oil and the like which are contained together with the poly(meth)acrylate.

<Metal-Based Detergent (F)>

[0107] It is preferable that the lubricating oil composition of the present embodiment further contains a metal-based detergent (F). By containing the metal-based detergent (F), production of a deposit in the inside of an engine at the time of high-temperature operation is suppressed, accumulation of a sludge is prevented to keep the inside of the engine clean, and acidic substance generated as a result of degradation and the like of an engine oil is neutralized to prevent corrosive wear.

[0108] Examples of the metal-based detergent (F) include an alkali metal-based detergent or an alkaline-earth metal-based detergent. Specific examples thereof include one or more metal-based detergents selected from alkali metal sulfonate or alkaline-earth metal sulfonate, alkali metal phenate or alkaline-earth metal phenate, alkali metal salicylate, or alkaline-earth metal salicylate. Further, examples of the alkali metal include sodium and potassium, examples of the alkaline-earth metal include magnesium and calcium, and among these, sodium which is an alkali metal, and magnesium and calcium which are alkaline-earth metals are preferable, and calcium is more preferable.

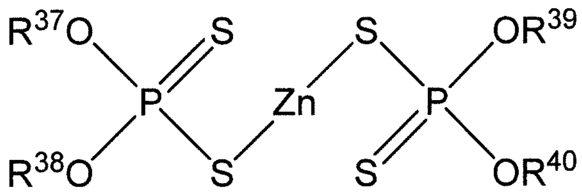
[0109] The metal-based detergent (F) may be neutral, basic, or overbasic, but is preferably basic or overbasic. Further, the total base number of the metal-based detergent (F) is preferably 10 to 500 mgKOH/g, and more preferably 150 to 450 mgKOH/g. Further, the total base number is one as measured in accordance with a perchloric acid method of JIS K2501.

[0110] From the viewpoint of exhibiting an effect based on the above-mentioned metal-based detergent (F), the content of the metal-based detergent (F) as converted into a metal amount in the lubricating oil composition of the present embodiment is preferably 0.05 to 0.50 mass%, and more preferably 0.10 to 0.30 mass%, based on the total amount of the lubricating oil composition.

<Zinc Dithiophosphate (G)>

[0111] It is preferable that the lubricating oil composition of the present embodiment further contains zinc dithiophosphate (G). By containing zinc dithiophosphate of the component (G), the friction-reducing effect can be more enhanced.

[0112] Examples of the zinc dithiophosphate (G) include those represented by the following general formula (VIII):


(VIII)

in the formula, R^{37} to R^{40} each independently represents any one selected from a linear, branched, or cyclic alkyl group having 6 to 20 carbon atoms, and a linear, branched, or cyclic alkenyl group having 6 to 20 carbon atoms.

[0113] By allowing the number of carbon atoms of R^{37} to R^{40} in the general formula (VIII) to be 6 to 20, a balance between the solubility in a lubricating base oil and the friction reduction can be enhanced.

[0114] The number of carbon atoms of the alkyl group or the alkenyl group of R^{37} to R^{40} in the general formula (VIII) is preferably 8 to 18, and more preferably 10 to 14. Further, R^{37} to R^{40} in the general formula (VIII) are each preferably an alkyl group.

[0115] Examples of the alkyl group in R^{37} to R^{40} 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 eicosyl group, a heneicosyl group, a docosyl group, a tricosyl group, and a tetracosyl group, and these may be linear, branched, or cyclic. Further, examples of the alkenyl group include a vinyl group, a propenyl group, a butenyl group, a pentenyl group, a hexenyl group, a heptenyl group, an octenyl group, a nonenyl group, a decenyl group, an undecenyl group, a dodecenyl group, a tridecenyl group, a tetradecenyl group, a pentadecenyl group, a hexadecenyl group, a heptadecenyl group, an octadecenyl group, a nonadecenyl group, an eicosenyl group, a heneicosenyl group, a docosenyl group, a tricosenyl group, and a tetracosenyl group. These may be linear, branched, or cyclic, and the position of the double bond is arbitrary.

[0116] In the general formula (VIII), R^{37} to R^{40} may be the same as or different from each other, and from the viewpoint of easiness in terms of production, they are preferably the same as each other.

[0117] Among these, dodecyl groups such as a lauryl group, octadecyl groups such as a tetradecyl group, a hexadecyl group, and a stearyl group, and octadecenyl groups such as an eicosyl group and an oleyl group are preferable, and a lauryl group is the most preferable.

[0118] From the viewpoint of a balance between friction reduction and abrasion resistance, the content of zinc dithiophosphate (G) is preferably 0.01 to 3.00 mass%, and more preferably 0.10 to 1.50 mass%, based on the total amount of the lubricating oil composition.

[0119] Furthermore, the content of zinc dithiophosphate (G) as converted into phosphorus atoms is preferably 100 to 2,000 ppm, more preferably 300 to 1,500 ppm, still more preferably 500 to 1,000 ppm, and even still more preferably 600 to 840 ppm, based on the total amount of the lubricating oil composition.

<Arbitrary Additive Components>

[0120] The lubricating oil composition of the present embodiment may contain arbitrary additive components such as succinimide not containing boron, an antioxidant, a rust inhibitor, a metal deactivator, a pour-point depressant, and an antifoaming agent as arbitrary components.

[0121] The content of these arbitrary additive components is approximately 0.01 to 5.00 mass% based on the total amount of the lubricating oil composition.

<Physical Properties of Lubricating Oil Composition>

[0122] From the viewpoint of friction reduction over a wide temperature range from a low temperature to a high temperature, it is preferable that the lubricating oil composition of the present embodiment has a kinematic viscosity at 40°C, a kinematic viscosity at 100°C, and an HTHS viscosity at 150°C, each of which falls within the following range.

[0123] The kinematic viscosity at 40°C is preferably 20 to 40 mm^2/s, and more preferably 20 to 35 mm^2/s.

[0124] The kinematic viscosity at 100°C is preferably 3.0 to 12.5 mm^2/s, and more preferably 4.0 to 9.3 mm^2/s.

[0125] The HTHS viscosity at 150°C is preferably 1.4 to 2.9 mPa·s, and more preferably 1.7 to 2.9 mPa·s.

[0126] Furthermore, the kinematic viscosity was measured in conformity with JIS K2283. The HTHS viscosity was measured using a TBS viscometer (tapered bearing simulator viscometer) in accordance with ASTM D4683 under the conditions at an oil temperature of 100°C, a shear rate of 10^6/s, a rotational speed (motor) of 3,000 rpm, and a clearance (clearance between a rotor and a stator) of 3 μm.

<Application of Lubricating Oil Composition>

[0127] The lubricating oil composition of the present embodiment is not particularly limited with respect to its application, but it can be suitably used for a variety of internal combustion engines of a four-wheel automobile, a two-wheel automobile, or the like. Further, among the internal combustion engines, the lubricating oil composition of the present embodiment can be particularly suitably used for a gasoline engine.

[Method for Reducing Friction of Internal Combustion Engine]

[0128] The method for reducing friction of an internal combustion engine of the present embodiment includes adding the above-mentioned lubricating oil composition of the present embodiment to an internal combustion engine.

[0129] According to the method for reducing friction of an internal combustion engine of the present embodiment, inhibition of a friction-reducing effect based on the molybdenum compound (B) is suppressed; and by the synergistic action with the molybdenum compound (B), and the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2), the friction-reducing effect is enhanced, and thus, the fuel consumption reducing properties can be enhanced. In a case where the internal combustion engine is a gasoline engine, the effect can be particularly enhanced.

EXAMPLES

[0130] Next, the present invention will be described in more detail with reference to Examples, but it should be construed that the present invention is by no means limited by these Examples.

1. Preparation of Lubricating Oil Compositions of Examples and Comparative Examples

[0131] Lubricating oil compositions of Examples and Comparative Examples were prepared in the compositions shown in Tables 1 to 3. Further, for the preparation of the lubricating oil compositions, the following materials were used.

<Lubricating Base Oil (A)>

[0132]

Mineral oil having a kinematic viscosity at 100°C: 4.07 mm^2/s, viscosity index: 131, $\%C_A$: -0.4, $\%C_N$: 12.8, and $\%C_P$: 87.6

<Molybdenum Compound (B)>

[0133]

Binuclear organic molybdenum compound of the general formula (I) (MoDTC having an Mo content of 10 mass%)

<Ester-Based Ashless Friction Modifier (C1)>

[0134]

Glycerin monooleate (number of hydroxyl groups in one molecule: 2)

<Amine-Based Ashless Friction Modifier (C2)>

[0135]

Alkyldiethanolamine (the number of carbon atoms of an alkyl group being a mixture of 12 to 20)

<Boratad succinimide (D)>

[0136]

Boratad polybutenylsuccinic bisimide (boron content: 1.3 mass%, nitrogen content: 1.2 mass%, amount of boron atoms/amount of nitrogen atoms: 1.1)

<Poly(meth)acrylate (E)>

[0137]

Polymethacrylate (weight average molecular weight of 440,000, content of the resin fraction of 17%, SSI of 30)

<Metal-Based Detergent (F)>

[0138]

Calcium-based detergent (calcium content: 12.1 mass%, overbasic, total base number: 350 mgKOH/g)

<Zinc Dithiophosphate (G)>

[0139]

ZnDTP (phosphorus content: 7.0 mass%, zinc content: 8.0 mass%, sulfur content: 14.0 mass%)

<Other Components>

[0140]

Polybutenylsuccinic bisimide which is not a boratad material, a hindered phenol-based antioxidant, a diphenylamine-based antioxidant, a pour-point depressant, a metal deactivator, and an antifoaming agent

2. Measurement and Evaluation

[0141] The lubricating oil compositions of Examples and Comparative Examples which had been prepared in the compositions shown in Tables 1 to 3 were subjected to the following evaluations. The results are shown in Tables 1 to 3.

2-1. HTHS Viscosity

[0142] In accordance with the disclosure of the present specification, the HTHS viscosity at 150°C of the lubricating oil composition was measured.

2-2. Friction Coefficient (HFRR Test)

[0143] Using an HFRR tester (manufactured by PCS Instruments), the friction coefficient of the lubricating oil composition was measured under the following conditions. A lower friction coefficient may indicate that the friction-reducing effect is superior and the fuel consumption reducing properties are better.

- Test piece: (A) Ball=HFRR standard test piece (AISI 52100 material), (B) Disc =HFRR standard test piece (AISI 52100 material)
- Amplitude: 1.0 mm
- Frequency: 50 Hz
- Load: 5 g
- Temperature: 80°C

[0144] In Tables 1 to 3, [mass% of Mo] represents the content of the molybdenum compound (B) as converted into molybdenum atoms based on the total amount of the lubricating oil composition; [mass% of B] represents the content of the boratad succinimide (D) as converted into boron atoms based on the total amount of the lubricating oil composition; and [mass% of Metal] represents the content of the metal-based detergent (F) as converted into metal atoms (calcium atoms) based on the total amount of the lubricating oil composition.

Table 1

			Example 1	Example 2	Comparative Example 1	Comparative Example 2
Composition	Lubricating base oil (A)	mass%	Balance	Balance	Balance	Balance
	Molybdenum compound (B)	mass%	0.7	0.7	0.7	0.7
	Ester-based friction modifier (C1)	mass%	0.5	-	-	-
	Amine-based friction modifier (C2)	mass%	-	0.5	-	2.0
	Boratad succinimide (D)	mass%	2.3	2.3	2.3	2.3
	Poly(meth)acrylate (E)	mass%	10.3	10.3	10.3	10.3
	Metal-based detergent (F)	mass%	1.65	1.65	1.65	1.65
	Zinc dithiophosphate (G)	mass%	1.14	1.14	1.14	1.14
	Other components	mass%	6.16	6.16	6.16	6.16
Properties of lubricating oil composition	Content of molybdenum derived from (B)	mass% of Mo	0.070	0.070	0.070	0.070
	Content of boron derived from (D)	mass% of B	0.030	0.030	0.030	0.030
	Content of metal derived from (F)	mass% of metal	0.200	0.200	0.200	0.200
	HTHS viscosity at 150°C	mPa·s	2.6	2.6	2.6	2.6
Evaluation	Friction coefficient	-	0.057	0.057	0.065	0.109

[0145] As is clear from the results of Table 1, it can be confirmed that the lubricating oil compositions of Examples 1 and 2, each including the molybdenum compound (B), and a specific amount of the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2), exhibit a better friction-reducing effect, as compared with the lubricating oil composition of Comparative Example 1, not including the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2).

[0146] It can also be confirmed that the lubricating oil composition of Comparative Example 2, including more than an appropriate amount of the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2) does not exhibit a good friction-reducing effect. The reason for this may be thought to be that the friction-reducing effect of the molybdenum compound (B) is inhibited by a large amount of the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2).

Table 2

			Example							Comparative Example 3
			3	4	5	6	7	8	9	
Composition	Lubricating base oil (A)	mass%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance
	Molybdenum compound (B)	mass%	0.7	0.7	0.7	0.7	0.3	0.7	0.7	0.7
	Ester-based friction modifier (C1) [X]	mass%	1.0	-	1.0	0.5	0.5	1.0	0.5	2.0
	Amine-based friction modifier (C2) [Y]	mass%	-	0.5	0.1	0.1	0.1	0.5	0.5	0.5
	Boratad succinimide (D)	mass%	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	Poly(meth)acrylate (E)	mass%	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
	Metal-based detergent (F)	mass%	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65
	Zinc dithiophosphate (G)	mass%	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
	Other components	mass%	6.16	6.16	6.16	6.16	6.16	6.16	6.16	6.16
Properties of lubricating oil composition	Content of molybdenum derived from (B)	mass% of Mo	0.070	0.070	0.070	0.070	0.030	0.070	0.070	0.070
	Content [Z] of boron derived from (C)	mass% of B	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
	Content of metal derived from (F)	mass% of Metal	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
	[Y]/[X]	-	-	-	0.10	0.20	0.20	0.50	1.00	0.25
	[Z]/[X+Y]	-	0.026	0.052	0.024	0.043	0.043	0.017	0.026	0.010
	HTHS viscosity at 150°C	mPa·s	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Evaluation	Friction coefficient	-	0.054	0.057	0.054	0.051	0.051	0.043	0.058	0.065

[0147] From the results shown in Table 2, it can be confirmed that by using the ester-based ashless friction modifier (C1) in combination with the amine-based ashless friction modifier (C2), and allowing the mass ratio ([Y]/[X]) of the content [Y] of the amine-based ashless friction modifier (C2) to the content [X] of the ester-based ashless friction modifier (C1) to be less than 1.0, the friction-reducing effect can be more enhanced. In particular, it can be confirmed that the lubricating oil compositions of Examples 6 to 8, each having [Y]/[X] of more than 0.10 and less than 1.00, exhibit a highly excellent friction-reducing effect.

[0148] In addition, in Comparative Example 3, the ester-based ashless friction modifier (C1) is used in combination with the amine-based ashless friction modifier (C2), but the friction coefficient increases. The reason for this may be thought to be that in Comparative Example 3, the total amount of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) is more than 1.8 mass% based on the total amount of the lubricating oil composition, so that the friction-reducing effect of the molybdenum compound (B) is inhibited.

Table 3

			Example 6	Example 10
Composition	Lubricating base oil (A)	mass%	Balance	Balance
	Molybdenum compound (B)	mass%	0.7	0.7
	Ester-based friction modifier (C1)	mass%	0.5	0.5
	Amine-based friction modifier (C2)	mass%	0.1	0.1
	Boratad succinimide (D)	mass%	2.3	-
	Poly(meth)acrylate (E)	mass%	10.3	12.0
	Metal-based detergent (F)	mass%	1.65	1.65
	Zinc dithiophosphate (G)	mass%	1.14	1.14
	Other components	mass%	6.16	6.16
Properties	Content of molybdenum derived from (B)	mass% of Mo	0.070	0.070
	Content of boron derived from (C)	mass% of B	0.030	-
	Content of metal derived from (F)	mass% of metal	0.200	0.200
	HTHS viscosity at 150°C	mPa·s	2.6	2.6
Evaluation	Friction coefficient	-	0.051	0.059

[0149] From the results shown in Table 3, it can be confirmed that the lubricating oil composition of Example 6, including the molybdenum compound (B), the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2), and the boratad succinimide (D) exhibits a better friction-reducing effect, as compared with the lubricating oil composition of Example 10, including the molybdenum compound (B), the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2), but not including the boratad succinimide (D). The reason for this may be thought to be that in the lubricating oil composition of Example 6, by using the molybdenum compound (B), and the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2), together with the boratad succinimide (D), a friction-reducing effect based on the molybdenum compound (B) is more easily retained, and by the synergistic action with the molybdenum compound (B), and the ester-based ashless friction modifier (C1) and/or the amine-based ashless friction modifier (C2), the friction-reducing effect is more enhanced.

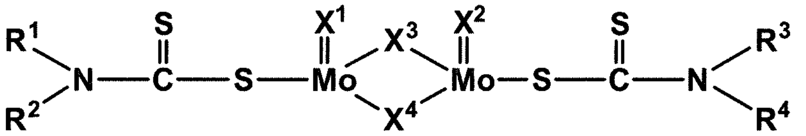
Industrial Applicability

[0150] The lubricating oil composition of the present embodiment exhibits a good friction-reducing effect, and thus, the fuel consumption reducing properties can be enhanced. For this reason, the lubricating oil composition of the present embodiment can be suitably used for a variety of internal combustion engines of a four-wheel automobile, a two-wheel automobile, or the like. Further, among the internal combustion engines, the lubricating oil composition of the present embodiment can be particularly suitably used for a gasoline engine.

Claims

1. A lubricating oil composition comprising:

   a lubricating base oil (A);
   a molybdenum compound (B); and
   an ashless friction modifier (C),
   wherein the lubricating oil composition includes a binuclear organic molybdenum compound represented by the following general formula (I) as the molybdenum compound (B), with the content of the binuclear organic molybdenum compound as converted into molybdenum atoms being 0.030 mass% or more and 0.140 mass% or less based on the total amount of the lubricating oil composition; and
   an ester-based ashless friction modifier (C1) and/or an amine-based ashless friction modifier (C2) as the ashless friction modifier (C), with the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) being more than 0.1 mass% and 1.8 mass% or less based on the total amount of the lubricating oil composition:

   (I)

   wherein R^1 to R^4 each represents a hydrocarbon group having 4 to 22 carbon atoms, R^1 to R^4 may be the same as or different from each other, and X^1 to X^4 each represents a sulfur atom or an oxygen atom.

2. The lubricating oil composition according to claim 1, wherein the ester-based ashless friction modifier (C1) is an ester compound having one or more hydroxyl groups in a molecule thereof.

3. The lubricating oil composition according to claim 2, wherein the ester compound having one or more hydroxyl groups in a molecule thereof is glycerin monooleate.

4. The lubricating oil composition according to any one of claims 1 to 3, which comprises the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) as the ashless friction modifier (C).

5. The lubricating oil composition according to claim 4, wherein the mass ratio between the content of the amine-based ashless friction modifier (C2) and the content of the ester-based ashless friction modifier (C1) [the content of the amine-based ashless friction modifier (C2)/the content of the ester-based ashless friction modifier (C1)] is less than 1.00.

6. The lubricating oil composition according to any one of claims 1 to 5, further comprising a boratad succinimide (D).

7. The lubricating oil composition according to claim 6, wherein the content of the boratad succinimide (D) as converted into boron atoms is 0.050 mass% or less based on the total amount of the lubricating oil composition.

8. The lubricating oil composition according to claim 6 or 7, wherein the mass ratio of the total content of the ester-based ashless friction modifier (C1) and the amine-based ashless friction modifier (C2) to the content of the boratad succinimide (D) as converted into boron atoms [the content of the boratad succinimide (D) as converted into boron atoms/(the content of the ester-based ashless friction modifier (C1) + the content of the amine-based ashless friction modifier (C2))] is 0.011 or more.

9. The lubricating oil composition according to any one of claims 1 to 8, further comprising a poly(meth)acrylate (E).

10. The lubricating oil composition according to any one of claims 1 to 9, further comprising a metal-based detergent (F).

11. The lubricating oil composition according to any one of claims 1 to 10, further comprising zinc dithiophosphate (G).

12. The lubricating oil composition according to any one of claims 1 to 11, wherein the lubricating base oil (A) is one or more selected from mineral oils or synthetic oils classified into Group 3 and Group 4 in the base oil classification of

the American Petroleum Institute.

13. The lubricating oil composition according to any one of claims 1 to 12, which is used for an internal combustion engine.

14. A method for reducing friction of an internal combustion engine, comprising adding the lubricating oil composition according to any one of claims 1 to 12 to an internal combustion engine.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/060168

A. CLASSIFICATION OF SUBJECT MATTER
See extra sheet.

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)
C10M141/12, C10M101/02, C10M107/02, C10M129/68, C10M129/76, C10M133/04, C10M135/18, C10M137/10, C10M139/00, C10M145/14, C10N10/04, C10N10/12, C10N30/00, C10N30/06, C10N40/25

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
JSTPlus/JMEDPlus/JST7580(JDreamIII), Japio-GPG/FX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2008-106199 A (Idemitsu Kosan Co., Ltd.), 08 May 2008 (08.05.2008), claims; paragraphs [0031] to [0038]; examples & US 2010/0029520 A1 claims; paragraphs [0037] to [0044]; examples & WO 2008/050681 A1 & EP 2080798 A1	1-3,6-14 4-5
X A	JP 2009-292998 A (Idemitsu Kosan Co., Ltd. et al.), 17 December 2009 (17.12.2009), claims; paragraphs [0039], [0045]; examples & EP 2133406 A1 claims; paragraphs [0060], [0067]; examples	1-3,6-14 4-5

☒ 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
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"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 20 April 2016 (20.04.16)	Date of mailing of the international search report 10 May 2016 (10.05.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/060168

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2010-100707 A (Idemitsu Kosan Co., Ltd. et al.), 06 May 2010 (06.05.2010), claims; paragraphs [0033] to [0035], [0040]; examples (Family: none)	1-3,6-14 4-5
X A	JP 2006-182986 A (Chevron Japan Ltd.), 13 July 2006 (13.07.2006), claims; paragraph [0033]; examples (Family: none)	1-3,6-14 4-5
X A	JP 2003-73685 A (Nippon Oil Corp.), 12 March 2003 (12.03.2003), claims; paragraphs [0017] to [0019], [0041]; examples (Family: none)	1-3,6-14 4-5
X A	JP 2004-277712 A (Nippon Oil Corp.), 07 October 2004 (07.10.2004), claims; paragraphs [0063] to [0073], [0081]; examples & CN 1524933 A	1-3,6-14 4-5
X A	WO 2010/032781 A1 (Idemitsu Kosan Co., Ltd.), 25 March 2010 (25.03.2010), claims; paragraph [0026]; examples & JP 5551599 B & US 2011/0166053 A1 claims; paragraph [0043]; examples & EP 2333037 A1	1-3,6-14 4-5
X A	WO 2014/021350 A1 (Idemitsu Kosan Co., Ltd.), 06 February 2014 (06.02.2014), claims; paragraph [0045]; examples & US 2015/0175927 A1 claims; paragraphs [0081], [0082]; examples & EP 2883946 A1	1-3,6-14 4-5
X A	JP 2011-195774 A (ADEKA Corp.), 06 October 2011 (06.10.2011), claims; paragraph [0034]; examples (Family: none)	1-3,6-14 4-5
X A	WO 2005/014763 A1 (Nippon Oil Corp.), 17 February 2005 (17.02.2005), claims; paragraphs [0019] to [0060], [0072]; examples & US 2007/0060483 A1 claims; paragraphs [0052] to [0133], [0156]; examples & EP 1661971 A1	1-3,6-14 4-5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/060168

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2003-221588 A (Asahi Denka Co., Ltd.), 08 August 2003 (08.08.2003), claims; paragraphs [0062], [0063], [0089], [0091]; examples (Family: none)	1-3,6-14 4-5
X A	JP 7-150173 A (Tonen Corp.), 13 June 1995 (13.06.1995), claims; paragraphs [0008], [0009]; examples (Family: none)	1-3,6-14 4-5
X A	WO 2015/022976 A1 (JX Nippon Oil & Energy Corp.), 19 February 2015 (19.02.2015), claims; paragraphs [0040], [0041], [0052]; examples (Family: none)	1-3,6-14 4-5
P,X	JP 2015-140354 A (Idemitsu Kosan Co., Ltd.), 03 August 2015 (03.08.2015), claims; examples & WO 2015/111746 A1	1-3,6-14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/060168

Continuation of A. CLASSIFICATION OF SUBJECT MATTER
(International Patent Classification (IPC))

C10M141/12(2006.01)i, *C10M101/02*(2006.01)n, *C10M107/02*(2006.01)n, *C10M129/68*(2006.01)n, *C10M129/76*(2006.01)n, *C10M133/04*(2006.01)n, *C10M135/18*(2006.01)n, *C10M137/10*(2006.01)n, *C10M139/00*(2006.01)n, *C10M145/14*(2006.01)n, *C10N10/04*(2006.01)n, *C10N10/12*(2006.01)n, *C10N30/00*(2006.01)n, *C10N30/06*(2006.01)n, *C10N40/25*(2006.01)n

(According to International Patent Classification (IPC) or to both national classification and IPC)

Form PCT/ISA/210 (extra sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2015010177 A **[0007]**
- WO 2011062282 A **[0007]**