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(54) **LUBRICATING OIL COMPOSITION**

(57) Provided is a lubricating oil composition which has an excellent effect of reducing the friction coefficient even when a member having a low surface roughness in a low oil temperature region is lubricated, by means of a lubricating oil composition which contains a mineral

base oil (A), a polymer (B) having a weight average molecular weight (Mw) of 100 to 15,000, and a molybdenum-based friction modifier (M) and has a kinematic viscosity at 40°C of 35.0 mm²/s or less.

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Description

Technical Field

5 **[0001]** The present invention relates to a lubricating oil composition

Background Art

10 **[0002]** In recent years, from the viewpoint of effective use of petroleum resources and reduction of CO₂ emissions, there is a strong demand for fuel saving of vehicles such as automobiles. Therefore, there is a strong demand for fuel saving also for lubricating oil compositions used for engines of vehicles such as automobiles.

[0003] As one method for saving fuel consumption, a method of reducing viscous resistance by reducing the viscosity of a lubricating oil composition can be mentioned, but merely promoting the viscosity reduction adversely affects the friction characteristics.

15 **[0004]** Further, in an automobile equipped with a hybrid mechanism or an idling stop mechanism, since the operating rate of the engine is low and the oil temperature does not easily rise, it is more important to lower the viscosity in a low oil temperature region, and low-viscosity mineral oil or synthetic oil may be used as a base oil. In this case, a molybdenum-based friction modifier may be used for the purpose of reducing the friction coefficient (for example, see PTL 1).

20 **[0005]** On the other hand, in recent years, techniques for reducing the surface roughness of engine members such as pistons and cylinder liners have been developed.

Citation List

Patent Literature

25 **[0006]** PTL 1: JP 2019-189668 A

Summary of Invention

Technical Problem

[0007] However, as a result of studies by the present inventors, it has been found that when a member having a small surface roughness is lubricated in a low oil temperature region, the friction coefficient is deteriorated.

35 **[0008]** The present invention has been made in view of the above problem, and an object of the present invention is to provide a lubricating oil composition having an excellent effect of reducing the friction coefficient even when lubricating a member having small surface roughness in a low oil temperature region.

Solution to Problem

40 **[0009]** As a result of intensive studies by the present inventors, it was found that the above-described problem can be solved by a low-viscosity lubricating oil composition blending a polymer having a specific weight average molecular weight with a molybdenum-based friction modifier, and the present invention has been completed.

[0010] That is, the present invention provides the following [1].

45 [1] A lubricating oil composition containing a mineral base oil (A), a polymer (B) having a weight average molecular weight (Mw) of 100 to 15,000, and a molybdenum-based friction modifier (M), wherein the lubricating oil composition has a kinematic viscosity at 40°C of 35.0 mm²/s or less.

Advantageous Effects of Invention

50 **[0011]** According to the present invention, it is possible to provide the lubricating oil composition having an excellent effect of reducing the friction coefficient even when lubricating a member having small surface roughness in a low oil temperature region.

Description of Embodiments

55 **[0012]** The upper limit values and the lower limit values of the numerical ranges described herein can be arbitrarily combined. For example, when "A to B" and "C to D" are described as numerical ranges, the numerical ranges of "A to

D" and "C to B" are also included in the scope of the present invention.

[0013] In addition, a numerical range "lower limit value to upper limit value" described herein means the lower limit value or more and the upper limit value or less, unless otherwise specified.

[0014] Further, in the description herein, numerical values of the Examples are numerical values that can be used as an upper limit value or a lower limit value.

[0015] In the description herein, for example, "(meth)acrylate" is used as a term indicating both "acrylate" and "methacrylate", and the same applies to other similar terms and similar notations.

[Lubricating Oil Composition]

[0016] The lubricating oil composition according to the present embodiment contains a mineral base oil (A), a polymer (B) having a weight average molecular weight (Mw) of 100 to 15,000, and a molybdenum-based friction modifier (M), and has a kinematic viscosity at 40°C of 35.0 mm²/s or less.

[0017] As a result of intensive studies to solve the above problem, the present inventors have found that, when a member having a small surface roughness is lubricated in a low oil temperature region, a film of a molybdenum-based friction modifier is less likely to be formed in a boundary lubrication region, and the friction coefficient is deteriorated.

[0018] Therefore, as a result of intensive studies by the present inventors, it was found that the friction coefficient between metal members in a low oil temperature region can be reduced by blending a polymer having a small molecular weight, and the present invention has been completed.

[0019] Hereinafter, each of the components contained in the lubricating oil composition according to the present embodiment will be described.

<Mineral Base Oil (A)>

[0020] The lubricating oil composition according to the present embodiment contains a mineral base oil (A). As the mineral base oil (A), one or more selected from mineral oils which have been conventionally used as lubricant base oils can be used without particular limitation.

[0021] Examples of the mineral oil include: an atmospheric residue obtained by atmospheric distillation of a crude oil such as a paraffinic crude oil, an intermediate crude oil, or a naphthenic crude oil; a lubricating oil distillate obtained by vacuum distillation of the atmospheric residue; and a mineral oil obtained by subjecting the lubricating oil distillate to one or more refining treatments such as solvent deasphalting, solvent extraction, hydrofinishing, hydrocracking, advanced hydrocracking, solvent dewaxing, catalytic dewaxing, and hydroisomerization dewaxing.

[0022] The mineral base oil (A) used in the present embodiment is preferably a base oil classified into Group II or III of the base oil category of API (American Petroleum Institute) and more preferably a base oil classified into Group III.

[0023] As the mineral base oil (A), one selected from the mineral oils may be used alone, or two or more thereof may be used in combination.

[0024] With respect to the kinematic viscosity and the viscosity index of the mineral base oil (A), the upper limit is preferably set in the following range from the viewpoint of improving fuel saving performance, and the lower limit is preferably set in the following range from the viewpoint of reducing the loss of the lubricating oil composition due to evaporation and ensuring oil film retention.

[0025] The 40°C kinematic viscosity of the mineral base oil (A) is preferably 4.0 mm²/s or more, more preferably 8.0 mm²/s or more, still more preferably 12.0 mm²/s or more, and is preferably 50.0 mm²/s or less, more preferably 35.0 mm²/s or less, and still more preferably 24.0 mm²/s or less. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, it is preferably 4.0 mm²/s to 50.0 mm²/s, more preferably 8.0 mm²/s to 35.0 mm²/s, and still more preferably 12.0 mm²/s to 24.0 mm²/s.

[0026] The 100°C kinematic viscosity of the mineral base oil (A) is preferably 2.0 mm²/s or more, and is preferably 20.0 mm²/s or less, more preferably 10.0 mm²/s or less, still more preferably 8.0 mm²/s or less, and even more preferably 7.0 mm²/s or less. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, it is preferably 2.0 mm²/s to 20.0 mm²/s, more preferably 2.0 mm²/s to 10.0 mm²/s, still more preferably 2.0 mm²/s to 8.0 mm²/s, and even more preferably 2.0 mm²/s to 7.0 mm²/s.

[0027] The viscosity index of the base oil (A) is preferably 80 or more, more preferably 90 or more, still more preferably 100 or more, even more preferably 105 or more, and yet still more preferably 120 or more.

[0028] The 40°C kinematic viscosity, the 100°C kinematic viscosity, and the viscosity index can be measured or calculated in accordance with JIS K 2283:2000.

[0029] In the case where the mineral base oil (A) is a mixed base oil containing two or more mineral base oils, the kinematic viscosity and the viscosity index of the mixed base oil are preferably within the above ranges.

[0030] In the lubricating oil composition according to the present embodiment, the content of the mineral base oil (A) is not particularly limited, but is preferably 60% by mass to 99% by mass, more preferably 70% by mass to 95% by

mass, and still more preferably 80% by mass to 93% by mass based on the total amount (100% by mass) of the lubricating oil composition, from the viewpoint of more easily exhibiting the effects of the present invention.

<Polymer (B)>

[0031] The polymer (B) used in the lubricating oil composition according to the present embodiment is required to have a weight average molecular weight (Mw) of 100 to 15,000. When the weight average molecular weight (Mw) of the polymer is less than 100, the effect of enhancing the oil film is not exhibited, and on the other hand, when the weight average molecular weight (Mw) of the polymer is more than 15,000, the polymer cannot enter the sliding surface, and therefore, the effect of reducing the friction coefficient is not exhibited in any case. The weight average molecular weight (Mw) of the polymer (B) is preferably 500 or more, more preferably 800 or more, and still more preferably 1,000 or more, and is preferably 13,000 or less, more preferably 12,000 or less, still more preferably 11,000 or less, and particularly preferably 3,500 or less. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, it is preferably 500 to 13,000, more preferably 800 to 12,000, still more preferably 1,000 to 11,000, and particularly preferably 1,000 to 3,500.

[0032] The number average molecular weight (Mn) of the polymer (B) is preferably 100 or more, more preferably 500 or more, still more preferably 700 or more, and particularly preferably 800 or more, and is preferably 10,000 or less, more preferably 5,000 or less, still more preferably 3,000 or less, and particularly preferably 1,700 or less. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, it is preferably 100 to 10,000, more preferably 500 to 5,000, still more preferably 700 to 3,000, and particularly preferably 800 to 1,700.

[0033] The molecular weight distribution (Mw/Mn) of the polymer (B) is preferably 3.0 or less, more preferably 2.5 or less, and still more preferably 2.0 or less.

[0034] In the description herein, the weight average molecular weight (Mw) and the number average molecular weight (Mn) of each component are values in terms of standard polystyrene measured by a gel permeation chromatography (GPC) method.

[0035] Examples of the polymer (B) include polyolefin, an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and naphthalene, a condensate of chlorinated paraffin and phenol, poly(meth)acrylate, and polyalkylstyrene.

[0036] As the polymer (B), it is preferable to use a polyolefin (B-1) or a poly(meth)acrylate (B-2).

[0037] The polyolefin (B-1) is preferably a polymer of an olefin having 2 or more carbon atoms, more specifically, an ethylene-propylene copolymer or a polymer of an olefin having 4 or more carbon atoms is more preferred, and on the other hand, a polymer of an olefin having 20 or less carbon atoms is preferred, and a polymer of an olefin having 12 or less carbon atoms is more preferred. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and as the polymer of an olefin having 4 or more carbon atoms, specifically, a polymer of an olefin having 4 to 20 carbon atoms is preferred, and a polymer of an olefin having 4 to 12 carbon atoms is more preferred.

[0038] Specific examples of the olefin include ethylene, propylene, 1-butene, 2-butene, isobutene, 3-methyl-1-butene, 4-phenyl-1-butene, 1-pentene, 3-methyl-1-pentene, 4-methyl-1-pentene, 3,3-dimethyl-1-pentene, 3,4-dimethyl-1-pentene, 4,4-dimethyl-1-pentene, 1-hexene, 4-methyl-1-hexene, 5-methyl-1-hexene, 6-phenyl-1-hexene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-pentadecene, 1-hexadecene, 1-heptadecene, 1-octadecene, 1-nonadecene, and 1-eicosene. Of these, 1-butene and 1-decene are preferred.

[0039] Further, the polyolefin (B-1) may be a hydrogenated product.

[0040] The content of the polymer (B) is preferably 0.1% by mass or more, more preferably 0.2% by mass or more, and still more preferably 0.3% by mass or more, and is preferably 5.0% by mass or less, more preferably 4.0% by mass or less, and still more preferably 3.0% by mass or less, in terms of solid content based on the total amount of the composition. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, the content is preferably 0.1 to 5.0% by mass, more preferably 0.2 to 4.0% by mass, and still more preferably 0.3 to 3.0% by mass.

[Molybdenum-based Friction Modifier (M)]

[0041] The lubricating oil composition according to the present embodiment further contains a molybdenum-based friction modifier (M). When the lubricating oil composition does not contain the molybdenum-based friction modifier (M), the friction reducing action becomes insufficient.

[0042] As the molybdenum-based friction modifier (M), any compound having a molybdenum atom can be used.

[0043] Examples of the molybdenum-based friction modifier (M) include molybdenum dithiocarbamate (MoDTC), molybdenum dithiophosphate (MoDTP), and a molybdenum amine complex. These may be used alone or may be used in combination of two or more thereof.

[0044] Among these, one or more selected from the group consisting of molybdenum dithiocarbamate (MoDTC) and

a molybdenum amine complex are preferable from the viewpoint of obtaining excellent fuel saving performance by reducing an inter-metal friction coefficient.

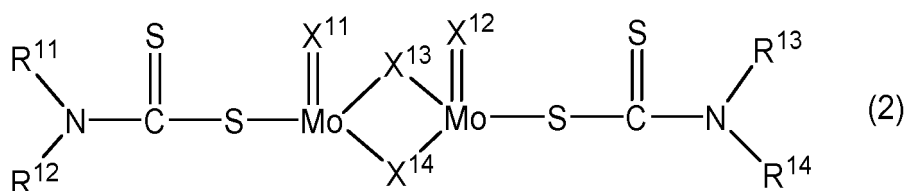
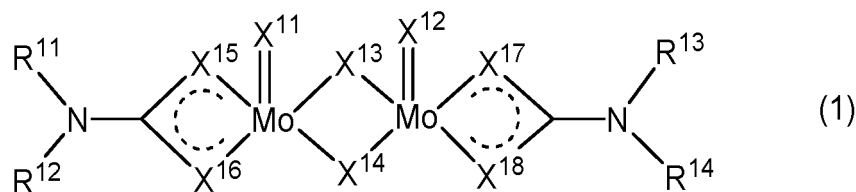
[0045] Examples of the molybdenum dithiocarbamate (MoDTC) include binuclear molybdenum dithiocarbamate containing two molybdenum atoms in one molecule, and trinuclear molybdenum dithiocarbamate containing three molybdenum atoms in one molecule.

[0046] That is, in the present embodiment, the molybdenum-based friction modifier (M) preferably includes one or more selected from the group consisting of binuclear molybdenum dithiocarbamate, trinuclear molybdenum dithiocarbamate, and a molybdenum amine complex, and more preferably includes two or more thereof.

[0047] Hereinafter, these molybdenum-based friction modifiers will be described in detail.

<Binuclear Molybdenum Dithiocarbamate>

[0048] Examples of the binuclear molybdenum dithiocarbamate include a compound represented by the following general formula (1) and a compound represented by the following general formula (2).



[0049] In the general formulae (1) and (2), R^{11} to R^{14} each independently represent a hydrocarbon group, and may be the same as or different from each other.

[0050] X^{11} to X^{18} each independently represent an oxygen atom or a sulfur atom, and may be the same as or different from each other. Provided that, at least two of X^{11} to X^{18} in the formula (1) are each a sulfur atom.

[0051] The number of carbon atoms of the hydrocarbon group which may be selected as R^{11} to R^{14} is preferably 6 to 22.

[0052] Examples of the hydrocarbon group which may be selected as R^{11} to R^{14} in the general formulae (1) and (2) include an alkyl group, an alkenyl group, a cycloalkyl group, an aryl group, an alkylaryl group, and an arylalkyl group. Examples of the alkyl group include 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, and an octadecyl group.

[0053] Examples of the alkenyl group include 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, and a pentadecenyl group.

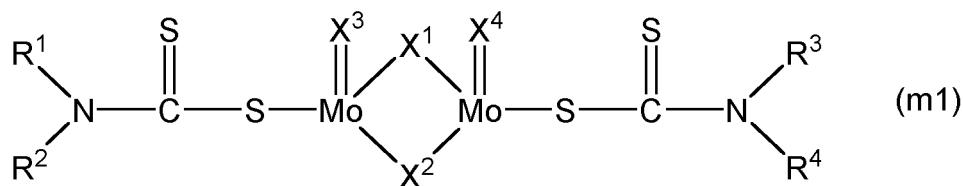
[0054] Examples of the cycloalkyl group include a cyclohexyl group, a dimethylcyclohexyl group, an ethylcyclohexyl group, a methylcyclohexylmethyl group, a cyclohexylethyl group, a propylcyclohexyl group, a butylcyclohexyl group, and a heptylcyclohexyl group.

[0055] Examples of the aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a biphenyl group, and a terphenyl group.

[0056] Examples of the alkylaryl group include a tolyl group, a dimethylphenyl group, a butylphenyl group, a nonylphenyl group, and a dimethylnaphthyl group.

[0057] Examples of the arylalkyl group include a methylbenzyl group, a phenylmethyl group, a phenylethyl group, and a diphenylmethyl group.

[0058] Among these, molybdenum dialkyldithiocarbamate (M1) represented by the following general formula (m1) (hereinafter, also referred to as "compound (M1)") is preferable.



10 **[0059]** In the general formula (m1), R¹, R², R³, and R⁴ each independently represent a short-chain substituent group (α) which is an aliphatic hydrocarbon group having 4 to 12 carbon atoms or a long-chain substituent group (β) which is an aliphatic hydrocarbon group having 13 to 22 carbon atoms. Provided that, the molar ratio $[(\alpha)/(\beta)]$ of the short-chain substituent group (α) to the long-chain substituent group (β) in the total molecule of the compound (M1) is 0.10 to 2.0. Further, in the general formula (m1), X¹, X², X³, and X⁴ each independently represent an oxygen atom or a sulfur atom.

15 **[0060]** Examples of the aliphatic hydrocarbon group having 4 to 12 carbon atoms which may be selected as the short-chain substituent group (α) include an alkyl group having 4 to 12 carbon atoms and an alkenyl group having 4 to 12 carbon atoms.

20 **[0061]** Specific examples thereof include 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 butenyl group, a pentenyl group, a hexenyl group, a heptenyl group, an octenyl group, a nonenyl group, a decenyl group, an undecenyl group, and a dodecenyl group. These may be a linear chain or a branched chain.

[0062] The number of carbon atoms of the aliphatic hydrocarbon group which may be selected as the short-chain substituent group (α) is preferably 5 to 11, more preferably 6 to 10, and still more preferably 7 to 9, from the viewpoint of more easily exhibiting the effects of the present invention.

25 **[0063]** Examples of the aliphatic hydrocarbon group having 13 to 22 carbon atoms which may be selected as the long-chain substituent group (β) include an alkyl group having 13 to 22 carbon atoms and an alkenyl group having 13 to 22 carbon atoms.

30 **[0064]** Specific examples thereof include 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 hencosyl group, a docosyl group, a tridecenyl group, a tetradecenyl group, a pentadecenyl group, a hexadecenyl group, a heptadecenyl group, an octadecenyl group, an oleyl group, a nonadecenyl group, an icosenyl group, a hencosenyl group, and a docosenyl group. These may be a linear chain or a branched chain.

[0065] The number of carbon atoms of the aliphatic hydrocarbon group which may be selected as the long-chain substituent group (β) is preferably 13 to 20, more preferably 13 to 16, and still more preferably 13 to 14, from the viewpoint of more easily exhibiting the effects of the present invention.

35 **[0066]** Here, in the compound (M1) represented by the general formula (m1), the molar ratio $[(\alpha)/(\beta)]$ of the short-chain substituent group (α) to the long-chain substituent group (β) in the total molecule thereof is 0.10 to 2.0. When the molar ratio $[(\alpha)/(\beta)]$ is 0.10 or more, the influence of the compound (M1) on the copper-corrosion resistance is reduced, and the friction reducing action is also easily improved. When the molar ratio $[(\alpha)/(\beta)]$ is 2.0 or less, the low-temperature storage stability is easily ensured.

40 **[0067]** Here, the molar ratio $[(\alpha)/(\beta)]$ is preferably 0.15 or more, and more preferably 0.20 or more, from the viewpoint of further reducing the influence on the copper corrosion resistance and from the viewpoint of more easily improving the friction reducing action.

[0068] On the other hand, the molar ratio $[(\alpha)/(\beta)]$ is preferably 1.2 or less, more preferably 1.0 or less, still more preferably 0.80 or less, and even more preferably 0.60 or less, from the viewpoint of more easily ensuring the low-temperature storage stability.

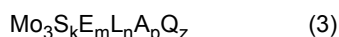
45 **[0069]** The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined. Specifically, it is preferably 0.15 to 1.2, more preferably 0.20 to 1.0, still more preferably 0.20 to 0.80, and even more preferably 0.20 to 0.60.

50 **[0070]** Here, the short-chain substituent group (α) and the long-chain substituent group (β) may be present together in the same molecule, or may not be present together in the same molecule. That is, it is only necessary that the mean value of the molar ratio $[(\alpha)/(\beta)]$ of the short-chain substituent group (α) to the long-chain substituent group (β) in the total molecule of the compound (M1) represented by the general formula (m1) is in the range of 0.10 to 2.0.

55 **[0071]** Therefore, in the compound (M1), a molecular group (m1-1) in which all of R¹, R², R³, and R⁴ in the general formula (m1) are the short-chain substituent group (α) may be mixed, a molecular group (m1-2) in which all of R¹, R², R³, and R⁴ are the long-chain substituent group (β) may be mixed, and a molecular group (m1-3) in which a part of R¹, R², R³, and R⁴ is the short-chain substituent group (α) and the rest is the long-chain substituent group (β) may be mixed.

<Trinuclear Molybdenum Dithiocarbamate>

[0072] Examples of the trinuclear molybdenum dithiocarbamate include a compound represented by the following general formula (3).



[0073] In the general formula (3), k is an integer of 1 or more; m is an integer of 0 or more; and $(k + m)$ is an integer of 4 to 10, and preferably an integer of 4 to 7. n is an integer of 1 to 4; and p is an integer of 0 or more. z is an integer of 0 to 5, inclusive of a non-stoichiometric value.

[0074] E's are each independently an oxygen atom or a selenium atom, and for example, are one capable of substituting sulfur in a core as mentioned later.

[0075] L's are each independently an anionic ligand having a carbon atom-containing organic group; a sum total of carbon atoms of the organic group in each of the ligands is 14 or more; and the respective ligands may be the same as or different from each other.

[0076] A's are each independently an anion other than L.

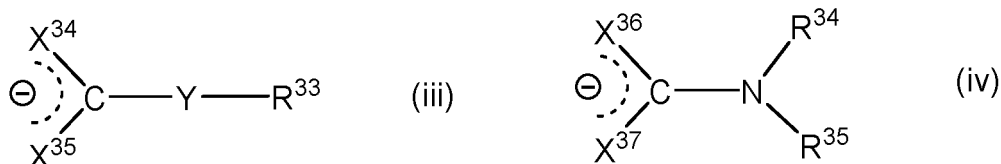
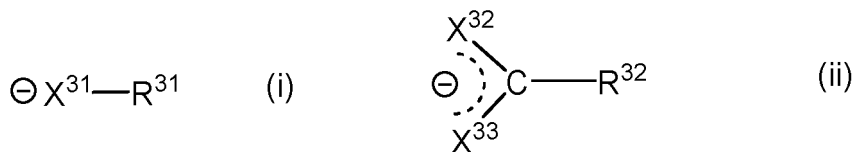
[0077] Q's are each independently a neutral compound capable of providing an electron and are existent for the purpose of fulfilling a vacant coordination site on the trinuclear molybdenum compound.

[0078] The sum total of carbon atoms of the organic group in the anionic ligand(s) represented by L is preferably 14 to 50, more preferably 16 to 30, and still more preferably 18 to 24.

[0079] As L, a monoanionic ligand that is a monovalent anionic ligand is preferred, and specifically, ligands represented by the following general formulae (i) to (iv) are more preferred.

[0080] In the general formula (3), the anionic ligand which is selected as L is preferably a ligand represented by the following general formula (iv).

[0081] In the general formula (3), it is preferred that all of the anionic ligands which are selected as L are the same, and it is more preferred that all of the anionic ligands selected as L are a ligand represented by the following general formula (iv).



[0082] In the general formulae (i) to (iv), X^{31} to X^{37} and Y are each independently an oxygen atom or a sulfur atom, and may be the same as or different from each other.

[0083] In the general formulae (i) to (iv), R^{31} to R^{35} are each independently an organic group, and may be the same as or different from each other.

[0084] The number of carbon atoms of each of the organic groups which may be selected as R^{31} , R^{32} , and R^{33} is preferably 14 to 50, more preferably 16 to 30, and still more preferably 18 to 24.

[0085] The total number of carbon atoms of the two organic groups which may be selected as R^{34} and R^{35} in the formula (iv) is preferably 14 to 50, more preferably 16 to 30, and still more preferably 18 to 24.

[0086] The number of carbon atoms of each of the organic groups which may be selected as R^{34} and R^{35} is preferably 7 to 30, more preferably 7 to 20, and still more preferably 8 to 13.

[0087] Although the organic group of R^{34} and the organic group of R^{35} may be the same as or different from each other, they are preferably different from each other. In addition, though the number of carbon atoms of the organic group of R^{34} and the number of carbon atoms of the organic group of R^{35} may be the same as or different from each other, they are preferably different from each other.

[0088] Examples of the organic group which is selected as R^{31} to R^{35} include a hydrocarbyl group, such as an alkyl group, an aryl group, a substituted aryl group, and an ether group.

[0089] The term "hydrocarbyl" expresses a substituent having a carbon atom, which is directly bonded to the residue

of the ligand, and in the scope of the present embodiment, characteristics thereof mainly rely on the hydrocarbyl. Examples of such a substituent include the following.

1. Hydrocarbon Substituent

[0090] Examples of the hydrocarbon substituent include aliphatic substituents, such as an alkyl group and an alkenyl group; alicyclic substituents, such as a cycloalkyl group and a cycloalkenyl group; and aromatic nuclei substituted with an aromatic group, an aliphatic group, or an alicyclic group; and cyclic groups in which the ring is completed via another site in the ligand (namely, arbitrarily expressed two substituents may each form an alicyclic group).

2. Substituted Hydrocarbon Substituent

[0091] Examples of the substituted hydrocarbon substituent include the aforementioned hydrocarbon substituents having, as the substituent, a non-hydrocarbon group which does not change the characteristics of the hydrocarbyl group. Examples of the non-hydrocarbon group include a halogen group, such as a chloro group and a fluoro group, an amino group, an alkoxy group, a mercapto group, an alkyl mercapto group, a nitro group, a nitroso group, and a sulfoxy group.

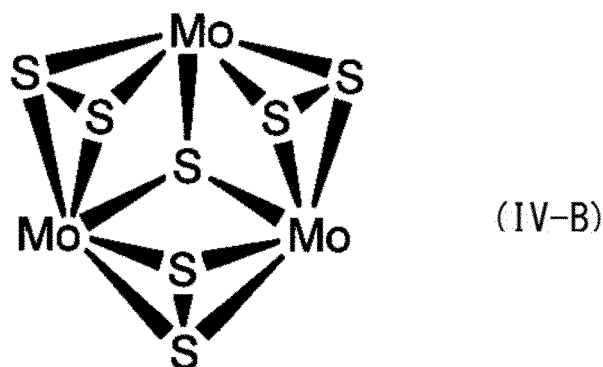
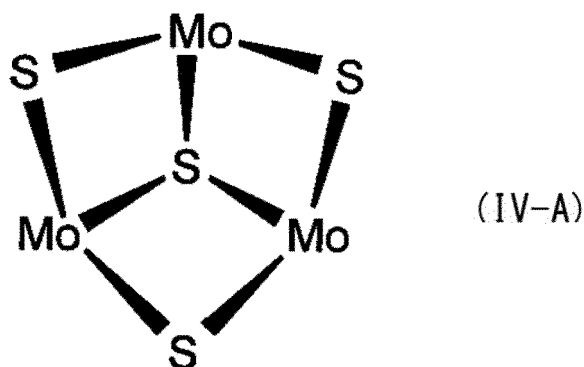
[0092] In the general formula (3), as the anionic ligand which is selected as L, ligands derived from an alkylxanthogenate, a carboxylate, a dialkyldithiocarbamate, or a mixture thereof are preferred, and ligands derived from a dialkyldithiocarbamate are more preferred.

[0093] In the general formula (3), the anion which may be selected as A may be either a monovalent anion or a divalent anion. Examples of the anion which may be selected as A include a disulfide, a hydroxide, an alkoxide, an amide, a thiocyanate, and derivatives thereof.

[0094] In the general formula (3), examples of Q include water, an amine, an alcohol, an ether, and a phosphine. Although Q's may be the same as or different from each other, they are preferably the same as each other.

[0095] As the trinuclear molybdenum dithiocarbamate, a compounds represented by the general formula (3) in which k is an integer of 4 to 7; n is 1 or 2; L is a monoanionic ligand; p is an integer of imparting electrical neutrality to the compound based on an anionic charge in A; and m and z are each 0 is preferred; and a compound in which k is an integer of 4 to 7; L is a monoanionic ligand; n is 4; and p, m, and z are each 0 is more preferred.

[0096] As the trinuclear molybdenum dithiocarbamate, for example, a compound having a core represented by the following formula (IV-A) or (IV-B) is preferred. Each core has a net electrical charge of +4. Such a core is surrounded by an anionic ligand and an optionally existing anion other than the anionic ligand.



[0097] Formation of the trinuclear molybdenum-sulfur compound requires selection of an appropriate anionic ligand (L) and other anion (A), depending on, for example, the number of sulfur and E atoms present in the core, i.e., the total anionic charge constituted of a sulfur atom, an E atom, if present, L, and A, if present, must be -4.

[0098] In the case where the anionic charge exceeds -4, the trinuclear molybdenum-sulfur compound may also contain a cation other than molybdenum, for example, an (alkyl)ammonium, an amine, or sodium. A preferred embodiment of the anionic ligand (L) and other anion (A) is a constitution having four monoanionic ligands.

[0099] The molybdenum-sulfur cores, for example, the structures represented by the aforementioned formulae (IV-A) and (IV-B), may be interconnected by means of one or more multidentate ligands, i.e., a ligand having more than one functional group capable of binding to a molybdenum atom to form oligomers.

<Molybdenum Amine Complex>

[0100] Examples of the molybdenum amine complex include molybdenum amine complexes obtained by reacting molybdenum trioxide and/or molybdic acid, which are hexavalent molybdenum compounds, with an amine compound.

[0101] Preferred examples of the amine compound include an alkylamine and a dialkylamine.

[0102] The alkylamine and dialkylamine to be reacted with the hexavalent molybdenum compound are not particularly limited, and examples thereof include an alkylamine and dialkylamine having an alkyl group having 1 to 30 carbon atoms.

<Content of Molybdenum-based Friction Modifier (M)>

[0103] In the lubricating oil composition according to the present embodiment, the content of the molybdenum-based friction modifier (M) is preferably 0.30% by mass or more, more preferably 0.40% by mass or more, and still more preferably 0.50% by mass or more, and is preferably 3.0% by mass or less, more preferably 2.0% by mass or less, and still more preferably 1.0% by mass or less, based on the total amount of the lubricating oil composition, from the viewpoint of reducing the inter-metal friction coefficient to obtain excellent fuel saving performance.

[0104] The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined. Specifically, the content is preferably 0.30% by mass to 3.0% by mass, more preferably 0.40% by mass to 2.0% by mass, and still more preferably 0.50% by mass to 1.0% by mass.

[0105] In the lubricating oil composition according to the present embodiment, the content of the molybdenum atom derived from the molybdenum-based friction modifier (M) is preferably 50 ppm by mass or more, more preferably 80 ppm by mass or more, and still more preferably 100 ppm by mass or more, and is preferably 2,000 ppm by mass or less, more preferably 1,500 ppm by mass or less, and still more preferably 1,000 ppm by mass or less, based on the total amount (100% by mass) of the lubricating oil composition, from the viewpoint of improving the friction reducing action. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, the content is preferably 50 to 2,000 ppm by mass, more preferably 80 to 1,500 ppm by mass, and still more preferably 100 to 1,000 ppm by mass.

<Content Ratio of Binuclear Molybdenum Dithiocarbamate to Molybdenum Amine Complex>

[0106] In the present embodiment, the content ratio of the binuclear molybdenum dithiocarbamate to the molybdenum amine complex [(binuclear MoDTC)/(MoAmn)] is preferably 0.1 to 10, more preferably 1.5 to 8.0, and still more preferably 3.0 to 7.0 in terms of mass ratio from the viewpoint of improving the friction reducing action.

<Other Components>

[0107] The lubricating oil composition according to the present embodiment may contain other components in addition to the above-described components as necessary, as long as the effects of the present invention are not impaired.

[0108] Examples of the additives as the other components include a metal-based detergent, a pour point depressant, an antioxidant, an anti-wear agent, a friction modifier other than the molybdenum-based friction modifier (M), an extreme pressure agent, a viscosity index improver, a rust inhibitor, an anti-foaming agent, an oiliness improver, a metal deactivator, and a demulsifier.

[0109] These may be used alone or may be used in combination of two or more thereof.

(Metal-based Detergent)

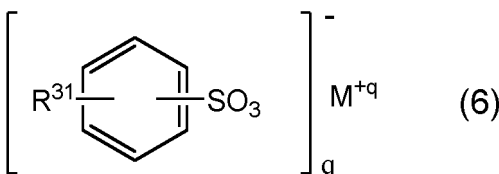
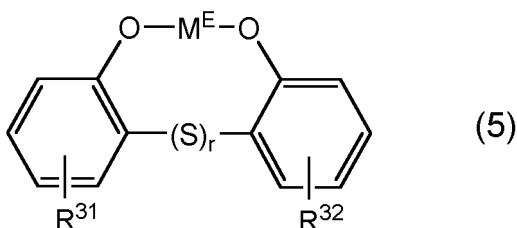
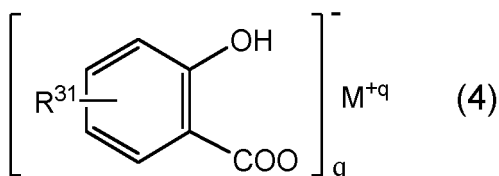
[0110] Examples of the metal-based detergent include an organic acid metal salt compound containing a metal atom selected from an alkali metal and an alkaline earth metal, and specific examples thereof include a metal salicylate, metal phenate, and metal sulfonate containing a metal atom selected from an alkali metal and an alkaline earth metal.

[0111] In the description herein, the "alkali metal" refers to lithium, sodium, potassium, rubidium, and cesium.

[0112] The "alkaline earth metal" refers to beryllium, magnesium, calcium, strontium, and barium.

[0113] The metal atom contained in the metal-based detergent is preferably sodium, calcium, magnesium, or barium, and more preferably calcium or magnesium, from the viewpoint of improving the detergency at high temperature.

[0114] The metal salicylate is preferably a compound represented by the following general formula (4), the metal phenate is preferably a compound represented by the following general formula (5), and the metal sulfonate is preferably a compound represented by the following general formula (6).



[0115] In the above general formulae (4) to (6), M is a metal atom selected from an alkali metal and an alkaline earth metal, preferably sodium, calcium, magnesium, or barium, and more preferably calcium or magnesium. M^E is an alkaline earth metal, preferably calcium, magnesium, or barium, and more preferably calcium or magnesium, q is the valence of M and is 1 or 2. R^{31} and R^{32} are each independently a hydrogen atom or a hydrocarbon group having 1 to 18 carbon atoms. S represents a sulfur atom. r is an integer of 0 or more, and preferably an integer of 0 to 3.

[0116] Examples of the hydrocarbon group which may be selected as R^{31} and R^{32} include an alkyl group having 1 to 18 carbon atoms, an alkenyl group having 1 to 18 carbon atoms, a cycloalkyl group having 3 to 18 ring carbon atoms, an aryl group having 6 to 18 ring carbon atoms, an alkylaryl group having 7 to 18 carbon atoms, and an arylalkyl group having 7 to 18 carbon atoms.

[0117] These may be used alone or may be used in combination of two or more thereof. Among these, one or more selected from calcium salicylate, calcium phenate, calcium sulfonate, magnesium salicylate, magnesium phenate, and magnesium sulfonate are preferable from the viewpoint of improving the high-temperature detergent dispersibility and from the viewpoint of the solubility in the base oil.

[0118] These metal-based detergents may be any of neutral salts, basic salts, overbased salts, and mixtures thereof.

[0119] The base number of the metal-based detergent is preferably 0 to 600 mgKOH/g.

[0120] When the metal-based detergent is a basic salt or an overbased salt, the base number of the metal-based detergent is preferably 10 to 600 mgKOH/g, and more preferably 20 to 500 mgKOH/g.

[0121] In the description herein, the term "base number" means a base number measured by a perchloric acid method in accordance with 7. of JIS K 2501:2003 "Petroleum products and lubricants - Determination of neutralization number".

[0122] In the lubricating oil composition according to the present embodiment, the content of the metal-based detergent is preferably 0.01% by mass to 10% by mass, more preferably 0.1% by mass to 5.0% by mass, still more preferably 0.2% by mass to 3.0% by mass, and even more preferably 0.3% by mass to 2.0% by mass, based on the total amount (100% by mass) of the lubricating oil composition, from the viewpoint of more easily exhibiting the effects of the present invention.

[0123] The metal-based detergent may be used alone or may be used in combination of two or more thereof. When two or more kinds are used, the preferable total content is also the same as the content described above.

[0124] In the lubricating oil composition according to the present embodiment, when the metal atom contained in the

metal-based detergent is calcium, the content of the calcium atom derived from the metal-based detergent is preferably 0.05% by mass or more, more preferably 0.10% by mass or more, and still more preferably 0.11% by mass or more, based on the total amount (100% by mass) of the lubricating oil composition, from the viewpoint of high-temperature detergent dispersibility.

[0125] On the other hand, the content of the calcium atom derived from the metal-based detergent is preferably 0.50% by mass or less, more preferably 0.40% by mass or less, still more preferably 0.30% by mass or less, even more preferably 0.20% by mass or less, yet still more preferably 0.15% by mass or less, and yet even more preferably 0.13% by mass or less, based on the total amount (100% by mass) of the lubricating oil composition, from the viewpoint of reducing the sulfated ash content and from the viewpoint of preventing LSPI (abnormal combustion).

[0126] In the lubricating oil composition according to the present embodiment, when the metal atom contained in the metal-based detergent is magnesium, the content of the magnesium atom derived from the metal-based detergent is preferably 0.02% by mass or more, more preferably 0.03% by mass or more, and still more preferably 0.04% by mass or more, based on the total amount (100% by mass) of the lubricating oil composition, from the viewpoint of high-temperature detergent dispersibility.

[0127] On the other hand, the content of the magnesium atom derived from the metal-based detergent is preferably 0.07% by mass or less, more preferably 0.06% by mass or less, and still more preferably 0.05% by mass or less, based on the total amount (100% by mass) of the lubricating oil composition, from the viewpoint of reducing the sulfated ash content and from the viewpoint of preventing LSPI (abnormal combustion).

(Pour Point Depressant)

[0128] Examples of the pour point depressant include an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and naphthalene, a condensate of chlorinated paraffin and phenol, polymethacrylate (PMA; polyalkyl (meth)acrylate and the like), polyvinyl acetate, polybutene, and polyalkylstyrene, and polymethacrylate is preferably used. In addition, the weight average molecular weight (Mw) of these polymers used as the pour point depressant is preferably 50,000 to 150,000.

[0129] These may be used alone or may be used in combination of two or more thereof.

(Antioxidant)

[0130] Examples of the antioxidant include an amine-based antioxidant and a phenol-based antioxidant.

[0131] Examples of the amine-based antioxidant include a diphenylamine-based antioxidant such as diphenylamine and an alkylated diphenylamine having an alkyl group having 3 to 20 carbon atoms; and a naphthylamine-based antioxidant such as phenyl- α -naphthylamine, phenyl- β -naphthylamine, a substituted phenyl- α -naphthylamine having an alkyl group having 3 to 20 carbon atoms, and a substituted phenyl- β -naphthylamine having an alkyl group having 3 to 20 carbon atoms.

[0132] Examples of the phenol-based antioxidant include a monophenol-based antioxidant such as 2,6-di-tert-butylphenol, 2,6-di-tert-butyl-4-methylphenol, 2,6-di-tert-butyl-4-ethylphenol, isooctyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate, and octadecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate; a diphenol-based antioxidant such as 4,4'-methylenebis(2,6-di-tert-butylphenol) and 2,2'-methylenebis(4-ethyl-6-tert-butylphenol); and a hindered phenol-based antioxidant.

[0133] These may be used alone or may be used in combination of two or more thereof.

(Anti-Wear agent)

[0134] Examples of the anti-wear agent include zinc-containing compounds such as zinc dialkyldithiophosphate (ZnDTP) and zinc phosphate; sulfur-containing compounds such as disulfides, sulfurized olefins, sulfurized oils and fats, sulfurized esters, thiocarbonates, thiocarbamates, and polysulfides; phosphorus-containing compounds such as phosphite esters, phosphate esters, phosphonate esters, and amine or metal salts thereof; and sulfur- and phosphorus-containing anti-wear agents such as thiophosphite esters, thiophosphate esters, thiophosphonate esters, and amine or metal salts thereof.

[0135] Among these, zinc dialkyldithiophosphate (ZnDTP) is preferable.

[0136] These may be used alone or may be used in combination of two or more thereof.

[0137] The content of the zinc dithiophosphate is preferably 200 to 5,000 ppm by mass, and more preferably 300 to 2,000 ppm by mass, in terms of phosphorus atom based on the total amount of the composition.

(Friction Modifier Other than Component (M))

[0138] The lubricating oil composition according to the present embodiment may contain a friction modifier other than the component (M).

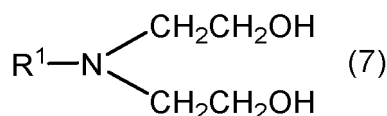
[0139] The component (M) is excellent in effectively exhibiting the friction reducing action in an environment in which the temperature of the lubricating oil composition is high, but by containing a friction modifier other than the component (M) in the lubricating oil composition, the friction reducing action can be effectively exhibited even in an environment in which the temperature of the lubricating oil composition is low.

[0140] Examples of the friction modifier other than the molybdenum-based friction modifier (M) include an ash-free friction modifier such as an aliphatic amine, a fatty acid ester, a fatty acid amide, a fatty acid, an aliphatic alcohol, and an aliphatic ether; an oil and fat; an amine, an amide, a sulfide ester, a phosphate ester, a phosphite ester, and a phosphate ester amine salt.

[0141] These may be used alone or may be used in combination of two or more thereof.

[0142] Here, as the friction modifier other than the component (M), an aliphatic amine is preferable, and among aliphatic amines, an aliphatic amine having at least one alkyl group or alkenyl group having 2 to 30 carbon atoms in the molecule is preferable.

[0143] Further, among the aliphatic amines having at least one alkyl group or alkenyl group having 2 to 30 carbon atoms in the molecule, a diethanolamine compound represented by the following general formula (7) is preferable.



[0144] In the general formula (7), R¹ is a monovalent aliphatic hydrocarbon group having 12 to 30 carbon atoms.

[0145] Preferred examples of the aliphatic hydrocarbon group having 12 to 30 carbon atoms of R¹ include a linear or branched alkyl group having 12 to 30 carbon atoms and a linear or branched alkenyl group having 12 to 30 carbon atoms. The number of carbon atoms in these groups is more preferably 12 to 24, and still more preferably 16 to 20.

[0146] Examples of the linear or branched alkyl group having 12 to 30 carbon atoms include various dodecyl groups such as n-dodecyl group, isododecyl group, sec-dodecyl group, tert-dodecyl group, and neododecyl group (hereinafter, functional groups having a predetermined number of carbon atoms including linear, branched, and isomers thereof may be abbreviated to "various functional groups"), various tridecyl groups, various tetradecyl groups, various pentadecyl groups, various hexadecyl groups, various heptadecyl groups, various octadecyl groups, various nonadecyl groups, various icosyl groups, various henicoyl groups, various docosyl groups, various tricosyl groups, various tetracosyl groups, various pentacosyl groups, various hexacosyl groups, various heptacosyl groups, various octacosyl groups, various nonacosyl groups, and various triacontyl groups.

[0147] Further, examples of the linear or branched alkenyl group having 12 to 30 carbon atoms include various dodecenyl groups, various tridecenyl groups, various tetradecenyl groups, various pentadecenyl groups, various hexadecenyl groups, various heptadecenyl groups, various octadecenyl groups, various nonadecenyl groups, various icosenyl groups, various henicosenyl groups, various docosenyl groups, various trichocenyl groups, various tetracocenyl groups, various pentacocenyl groups, various hexacocenyl groups, various heptacocenyl groups, various octacocenyl groups, various nonacocenyl groups, and various triacontinyl groups.

[0148] Among these, in consideration of the effect of improving the durability, various hexadecyl groups, various heptadecyl groups, and various octadecyl groups which are alkyl groups having 16 to 18 carbon atoms, and various hexadecenyl groups, various heptadecenyl groups, and various octadecenyl groups which are alkenyl groups having 16 to 18 carbon atoms are preferable, various hexadecyl groups, various octadecyl groups, and various octadecenyl groups are more preferable, and a n-hexadecyl group (a palmityl group), a n-octadecyl group (a stearyl group), and a n-octadecenyl group (an oleyl group) are still more preferable.

[0149] Preferred specific compounds of the diethanolamine compound represented by the general formula (7) include one or more selected from stearyldiethanolamine (in the general formula (7), R¹ is a n-octadecyl group (a stearyl group)), oleyldiethanolamine (in the general formula (7), R¹ is a n-octadecenyl group (an oleyl group)), and palmityldiethanolamine (in the general formula (7), R¹ is a n-hexadecyl group (a palmityl group)). Among these, oleyldiethanolamine is preferable.

[0150] These may be used alone or may be used in combination of two or more thereof.

(Extreme Pressure Agent)

[0151] Examples of the extreme pressure agent include a sulfur-based extreme pressure agent such as a sulfide, a sulfoxide, a sulfone, and a thiophosphinate, a halogen-based extreme pressure agent such as a chlorinated hydrocarbon,

and an organic metal-based extreme pressure agent. In addition, among the above-described anti-wear agents, a compound having a function as an extreme pressure agent can also be used.

[0152] These may be used alone or may be used in combination of two or more thereof.

5 (Rust Inhibitor)

[0153] Examples of the rust inhibitor include a fatty acid, an alkenyl succinic acid half ester, a fatty acid soap, an alkyl sulfonate, a polyhydric alcohol fatty acid ester, a fatty acid amine, an oxidized paraffin, and an alkyl polyoxyethylene ether.

[0154] These may be used alone or may be used in combination of two or more thereof.

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(Anti-foaming Agent)

[0155] Examples of the anti-foaming agent include a silicone oil such as dimethylpolysiloxane, a fluorosilicone oil, and a fluoroalkyl ether.

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[0156] These may be used alone or may be used in combination of two or more thereof.

(Oiliness Improver)

[0157] Examples of the oiliness improver include an aliphatic saturated or unsaturated monocarboxylic acid such as stearic acid and oleic acid; a polymerized fatty acid such as dimer acid and hydrogenated dimer acid; a hydroxy fatty acid such as ricinoleic acid and 12-hydroxystearic acid; an aliphatic saturated or unsaturated monoalcohol such as lauryl alcohol and oleyl alcohol; an aliphatic saturated or unsaturated monoamine such as stearylamine and oleylamine; an aliphatic saturated or unsaturated monocarboxylic acid amide such as lauric acid amide and oleic acid amide; and a partial ester of a polyhydric alcohol and an aliphatic saturated or unsaturated monocarboxylic acid, such as glycerin and sorbitol.

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(Metal Deactivator)

[0158] 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.

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[0159] These may be used alone or may be used in combination of two or more thereof.

(Demulsifier)

[0160] Examples of the demulsifier include anionic surfactants such as sulfuric acid ester salts of castor oil and petroleum sulfonic acid salts; cationic surfactants such as quaternary ammonium salts and imidazolines; polyalkylene glycol-based nonionic surfactants such as polyoxyethylene alkyl ethers, polyoxyethylene alkyl phenyl ethers, and polyoxyethylene alkyl naphthyl ethers; polyoxyalkylene polyglycols and esters of dicarboxylic acids thereof; and alkylene oxide adducts of alkylphenol-formaldehyde polycondensates.

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[0161] These may be used alone or may be used in combination of two or more thereof.

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[0162] The content of the other components described above can be appropriately adjusted within a range that does not impair the effects of the present invention, but each of the contents is usually 0.001% by mass to 15% by mass, preferably 0.005% by mass to 10% by mass, more preferably 0.01% by mass to 7% by mass, and still more preferably 0.03% by mass to 5% by mass, based on the total amount (100% by mass) of the lubricating oil composition.

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[0163] In the description herein, the additives as the other components may be mixed with the other components in the form of a solution obtained by diluting and dissolving the additives in a part of the mineral base oil (A) in consideration of handleability, solubility in the mineral base oil (A), and the like. In such a case, in the description herein, the above-mentioned content of the additives as the other components means the content in terms of active component (in terms of resin component) excluding a diluent oil.

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<Physical Properties of Lubricating Oil Composition>

<40°C Kinematic Viscosity, 100°C Kinematic Viscosity, and Viscosity Index>

[0164] The 40°C kinematic viscosity of the lubricating oil composition according to the present embodiment is preferably 5.0 mm²/s or more, more preferably 10.0 mm²/s or more, and still more preferably 15.0 mm²/s or more, and is preferably 65.0 mm²/s or less, more preferably 45.0 mm²/s or less, and still more preferably 30.0 mm²/s or less, from the viewpoint of improving fuel saving performance with respect to the upper limit value and from the viewpoint of reducing the loss

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of the lubricating oil composition due to evaporation and ensuring oil film retention with respect to the lower limit value. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, it is preferably 5.0 to 65.0 mm²/s, more preferably 10.0 to 45.0 mm²/s, and still more preferably 15.0 to 30.0 mm²/s.

[0165] The 100°C kinematic viscosity of the lubricating oil composition according to the present embodiment is preferably 3.0 mm²/s or more, more preferably 3.5 mm²/s or more, and still more preferably 4.0 mm²/s or more, and is preferably 9.3 mm²/s or less, more preferably 8.2 mm²/s or less, and still more preferably 7.1 mm²/s or less, from the viewpoint of improving fuel saving performance with respect to the upper limit value and from the viewpoint of reducing the loss of the lubricating oil composition due to evaporation and ensuring oil film retention with respect to the lower limit value. The upper limit values and the lower limit values of these numerical ranges can be arbitrarily combined, and specifically, it is preferably 3.0 to 9.3 mm²/s, more preferably 3.5 to 8.2 mm²/s, and still more preferably 4.0 to 7.1 mm²/s.

[0166] The viscosity index of the lubricating oil composition according to the present embodiment is preferably 100 or more, more preferably 110 or more, still more preferably 120 or more, and even more preferably 130 or more. When the viscosity index is within the above range, the viscosity change due to the temperature becomes small.

[0167] The 40°C kinematic viscosity, the 100°C kinematic viscosity, and the viscosity index can be measured or calculated in accordance with JIS K 2283:2000.

[150°C HTHS Viscosity (HTHS₁₅₀)]

[0168] The 150°C HTHS viscosity (HTHS₁₅₀) of the lubricating oil composition according to the present embodiment is preferably 1.5 mPa s or more, and more preferably 1.7 mPa s or more, and is preferably less than 3.7 mPa s, and more preferably less than 3.0 mPa s.

[0169] The 150°C HTHS viscosity (HTHS₁₅₀) of the lubricating oil composition according to the present embodiment can be measured in accordance with ASTM D 4683 using a TBS-high temperature viscosimeter (Tapered Bearing Simulator Viscosimeter) at a shear rate of 10⁶/s.

[Friction Coefficient]

[0170] The friction coefficient when the lubricating oil composition according to the present embodiment is used can be evaluated by using, for example, an SRV tester (manufactured by Optimol Co., Ltd.). Specifically, it can be evaluated by the method described in Examples described later. The lubricating oil composition according to the present embodiment preferably has a friction coefficient of 0.097 or less, and more preferably 0.095 or less under conditions in which the oil temperature is 30°C and the maximum height roughness (Rz) of the disk surfaces is less than 0.20 μm.

[Use of Lubricating Oil Composition]

[0171] The lubricating oil composition according to the present embodiment has an excellent effect of reducing the friction coefficient.

[0172] Therefore, the lubricating oil composition according to the present embodiment is preferably used for internal combustion engines, and more preferably used for internal combustion engines of four wheeled vehicles and motorcycles.

[0173] The lubricating oil composition according to the present embodiment is preferably used as an engine oil, but is more preferably used as an engine oil for an automobile engine equipped with a hybrid mechanism or an idling stop mechanism because the lubricating oil composition has an excellent effect of reducing a friction coefficient in a low temperature region.

[0174] In addition, the lubricating oil composition according to the present embodiment is suitable for use as a lubricating oil composition for internal combustion engines (engine oils for internal combustion engines) used in automobiles and the like, but can also be applied to other uses.

[0175] Further, since the lubricating oil composition according to the present embodiment has an effect of significantly reducing the friction coefficient between members having small surface roughness, it is also suitable as an engine oil for an engine in which the inside of a cylinder bore of an engine block is mirror-finished. More specifically, in the engine using the lubricating oil composition according to the present embodiment, the maximum height roughness (Rz) inside the cylinder bore is preferably less than 0.45 μm, more preferably less than 0.30 μm, and still more preferably less than 0.20 μm.

[0176] Specifically, the maximum height roughness (Rz) can be measured in accordance with JIS B 0601-2001.

[Method for Producing Lubricating Oil Composition]

[0177] The method for producing the lubricating oil composition according to the present embodiment is not particularly limited.

[0178] For example, the method for producing the lubricating oil composition according to the present embodiment includes a step of mixing the mineral base oil (A), the polymer (B), and the molybdenum-based friction modifier (M). If necessary, one or more selected from the other components described above may be further mixed.

[0179] The method for mixing the above-described components is not particularly limited, and examples thereof include a method including a step of blending respective components (the component (B), the component (M), and one or more selected from the other components) into the mineral base oil (A). Further, the respective components may be blended in the form of a solution (dispersion) by adding a diluent oil or the like. After the respective components are blended, it is preferable to uniformly disperse the components by stirring according to a known method.

[Engine]

[0180] The present embodiment also provides an engine including the lubricating oil composition of the present invention described above.

[0181] As described above, examples of the engine include an engine for a vehicle such as an automobile, but an engine for an automobile is preferable, and an engine for an automobile equipped with a hybrid mechanism or an idling stop mechanism in which the oil temperature is likely to decrease is more preferable.

[0182] Further, in the engine of the present embodiment, the maximum height roughness (Rz) of the cylinder bore inner surface of the engine block is preferably less than 0.45 μm , more preferably less than 0.30 μm , and still more preferably less than 0.20 μm , for the reasons described above.

[Method for Lubricating Engine]

[0183] The present invention also provides a method for lubricating an engine, including lubricating an engine using the lubricating oil composition according to the present embodiment described above.

[0184] The engine to be lubricated by the lubrication method of the present embodiment is the same as the engine provided by the present invention described above.

[0185] That is, a preferred aspect of the method for lubricating an engine according to the present embodiment is a method for lubricating an engine of an automobile equipped with a hybrid mechanism or an idling stop mechanism, which includes lubricating an engine in which the maximum height roughness (Rz) of the cylinder bore inner surface of the engine block is preferably less than 0.45 μm , more preferably less than 0.30 μm or less than 0.20 μm , using the lubricating oil composition of the present invention described above.

[One Aspect of the Invention Provided]

[0186] According to one aspect of the present invention, the following [1] to [9] are provided.

[1] A lubricating oil composition containing a mineral base oil (A), a polymer (B) having a weight average molecular weight (Mw) of 100 to 15,000, and a molybdenum-based friction modifier (M), wherein the lubricating oil composition has a kinematic viscosity at 40°C of 35.0 mm^2/s or less.

[2] The lubricating oil composition as set forth in [1], wherein the content of the polymer (B) is 0.1 to 5.0% by mass based on the total amount of the lubricating oil in terms of solid content.

[3] The lubricating oil composition as set forth in [1] or [2], wherein the polymer (B) is a polyolefin (B-1).

[4] The lubricating oil composition as set forth in any of [1] to [3], wherein the weight average molecular weight (Mw) of the polymer (B) is 1,000 to 11,000.

[5] The lubricating oil composition as set forth in any of [1] to [4], wherein the molybdenum-based friction modifier (M) contains two or more selected from a binuclear molybdenum dithiocarbamate, a trinuclear molybdenum dithiocarbamate, and a molybdenum amine complex.

[6] The lubricating oil composition as set forth in any of [1] to [5], wherein the content of the molybdenum-based friction modifier (M) is 50 to 2,000 ppm by mass in terms of molybdenum atom based on the total amount of the composition.

[7] The lubricating oil composition as set forth in any of [1] to [6], which is used in an engine provided with a member having a maximum height roughness (Rz) of the surface of less than 0.45 μm .

[8] The lubricating oil composition as set forth in any of [1] to [7], which is used in an automobile engine equipped with a hybrid mechanism or an idling stop mechanism.

[9] A method for lubricating an engine, including lubricating an engine provided with a member having a maximum height roughness (Rz) of the surface of less than 0.45 μm using the lubricating oil composition as set forth in any of [1] to [7].

Examples

[0187] The present invention will be specifically described by the following Examples, but the present invention is not limited to the following Examples. In addition, various properties of each of the components used in Examples and Comparative Examples and the obtained lubricating oil composition were measured by the following methods.

[40°C Kinematic Viscosity, 100°C Kinematic Viscosity, and Viscosity Index]

[0188] The 40°C kinematic viscosity, the 100°C kinematic viscosity, and the viscosity index of the lubricating oil composition were measured or calculated in accordance with JIS K 2283:2000.

[150°C HTHS Viscosity]

[0189] The 150°C HTHS viscosity was measured or calculated in accordance with JPI-5S-36-03.

[Contents of Molybdenum Atom and Phosphorus Atom]

[0190] The contents of a molybdenum atom and a phosphorus atom were measured in accordance with JPI-5S-38-03.

[Weight Average Molecular Weight (Mw), Number Average Molecular Weight (Mn), Molecular Weight Distribution (Mw/Mn)]

[0191] One column "TSKguardcolumn SuperHZ-L" and two columns "TSK SuperMultipore HZ-M" manufactured by Tosoh Corporation were attached to "1515 Isocratic HPLC Pump" and "2414 Differential Refractive Index (RI) Detector" manufactured by Waters Corporation in this order from the upstream side, and the measurement was performed under the conditions of measurement temperature: 40°C, moving phase: tetrahydrofuran, flow rate: 0.35 mL/min, sample concentration: 1.0 mg/mL, and calculated in terms of standard polystyrene.

[Examples 1 toll and Comparative Examples 1 to 4]

[0192] Each of the components shown below was added in the content shown in Table 1 and sufficiently mixed to obtain a lubricating oil composition.

[0193] Details of each of the components used in Examples 1 to 11 and Comparative Examples 1 to 4 are as follows.

[0194] In addition, the content in Table 1 is a content in terms of resin content.

<Base Oil (A)>

[0195]

· Mineral oil 1 (classified in API base oil category: Group III, 40°C kinematic viscosity: 19.8 mm²/s, 100°C kinematic viscosity: 4.0 mm²/s, viscosity index: 125)

· Mineral oil 2 (classified in API base oil category: Group II, 40°C kinematic viscosity: 406.6 mm²/s, 100°C kinematic viscosity: 30.6 mm²/s, viscosity index: 106)

<Polymer>

[Polymer corresponding to Component (B)]

[0196]

· Polymer 1 (olefin oligomer, weight average molecular weight (Mw): 2,500, number average molecular weight (Mn): 1,600, molecular weight distribution (Mw/Mn): 1.6)

· Polymer 2 (olefin oligomer, weight average molecular weight (Mw): 4,800, number average molecular weight (Mn): 3,000, molecular weight distribution (Mw/Mn): 1.6)

· Polymer 3 (olefin oligomer, weight average molecular weight (Mw): 10,000, number average molecular weight (Mn): 5,900, molecular weight distribution (Mw/Mn): 1.7)

· Polymer 4 (poly α -olefin, weight average molecular weight (Mw): 6,600, number average molecular weight (Mn): 3,300, molecular weight distribution (Mw/Mn): 2.0)

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- Polymer 5 (poly α -olefin, weight average molecular weight (M_w): 1,100, number average molecular weight (M_n): 900, molecular weight distribution (M_w/M_n): 1.2)
- Polymer 6 (polybutene, weight average molecular weight (M_w): 5,300, number average molecular weight (M_n): 4,500, molecular weight distribution (M_w/M_n): 1.2)
- Polymer 7 (polybutene, weight average molecular weight (M_w): 8,100, number average molecular weight (M_n): 6,600, molecular weight distribution (M_w/M_n): 1.2)
- Polymer 8 (polybutene, weight average molecular weight (M_w): 14,000, number average molecular weight (M_n): 10,000, molecular weight distribution (M_w/M_n): 1.4)

[Other Polymers]

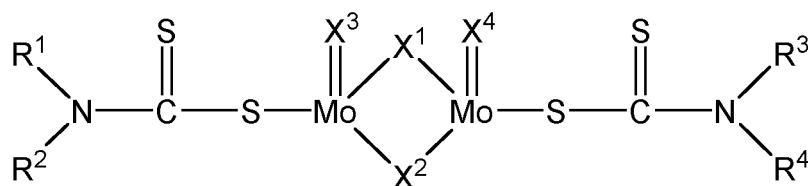
[0197]

- Polymer 9 (olefin oligomer, weight average molecular weight (M_w): 17,000, number average molecular weight (M_n): 11,000, molecular weight distribution (M_w/M_n): 1.5)
- Polymer 10 (polymethacrylate, weight average molecular weight (M_w): 26,000, number average molecular weight (M_n): 19,000, molecular weight distribution (M_w/M_n): 1.4)

<Molybdenum-based Friction Modifier (M)>

[0198]

- Molybdenum DTC: molybdenum dialkyldithiocarbamate (MoDTC, content of molybdenum atom: 10.0% by mass) represented by the following structural formula:



[In the above structural formula, R¹, R², R³, and R⁴ are each independently selected from an isooctyl group (having 8 carbon atoms: a short-chain substituent group) and an isotridecyl group (having 13 carbon atoms: a long-chain substituent group), the molar ratio of the isooctyl group to the isotridecyl group in the total molecule of molybdenum dialkyldithiocarbamate is 50:50, X¹ and X² are each a sulfur atom, and X³ and X⁴ are each an oxygen atom.]

- Molybdenum amine complex: (molybdenum atom content: 7.9% by mass)
- Trinuclear molybdenum dithiocarbamate: (MoDTC, molybdenum atom content: 10% by mass)

<Other Components>

Pour point depressant, antioxidant, zinc dialkyldithiophosphate (ZnDTP)

[Atom Content]

[0199] In Table 1, the content of molybdenum atoms in the lubricating oil composition is a value reflecting the content of molybdenum atoms derived from the molybdenum-based friction modifier (M).

[0200] In Tables 1 and 2, the content of phosphorus atoms in the lubricating oil composition is a value reflecting the content of phosphorus atoms derived from ZnDTP which is another additive.

[0201] Each of the lubricating oil compositions obtained in Examples 1 to 11 and Comparative Examples 1 to 4 was evaluated as follows. The results are shown in Table 1.

[Evaluation of Friction Coefficient]

[0202] By using an SRV tester (manufactured by Optimol Co., Ltd.) under the following conditions, the friction coefficient when using the prepared lubricating oil composition was measured.

[0203] First, a test was performed while sliding under the following conditions for 5 minutes at each temperature while

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raising the temperature from 30°C to 140°C every 10 degrees Celsius.

[0204] During the final 1 minute in the above-described test at 140°C, the friction coefficient was measured every second, and the average value of the friction coefficient during the final 1 minute was calculated.

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 - Cylinder: AISI52100
 - Standard disk: AISI52100 (maximum height roughness (Rz): 0.45 to 0.65 μm)
 - Mirror-finished disk: AISI52100 (maximum height roughness (Rz): less than 0.20 μm)
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 - Frequency: 50 Hz
 - Amplitude: 1.5 mm
 - Load: 400 N
 - Temperature: 30 to 140°C, Raise temperature every 10 degrees Celsius
 - Test time: 5 minutes at each temperature

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Table 1

(continued)

			Example											Comparative Example			
			1	2	3	4	5	6	7	8	9	10	11	1	2	3	4
Molybdenum-based friction modifier (C)	Molybdenum DTC	% by mass	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Molybdenum amine complex	% by mass	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.1	0.1	0.1	0.1
	Trinuclear molybdenum	% by mass											0.1				
Other component			10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
Total			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Physical properties	40°C kinematic viscosity	mm2/s	23.5	23.6	23.5	23.6	23.6	23.5	23.6	23.5	23.6	23.7	23.5	23.5	23.5	23.7	23.6
	100°C kinematic viscosity	mm2/s	5.0	5.0	4.9	5.0	5.0	5.0	5.0	4.9	5.0	5.0	5.0	4.9	5.0	5.0	5.0
	Viscosity index	-	141	141	139	141	141	141	140	140	141	142	141	139	139	142	141
	150°C HTHS viscosity	mPa·s	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Atom content in lubricating oil composition	Molybdenum	% by mass	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	Phosphorous	% by mass	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Friction coefficient evaluation	Mirror-finished disk	30°C	0.093	0.098	0.097	0.096	0.092	0.095	0.094	0.095	0.088	0.088	0.094	0.100	0.100	0.101	0.100
		80°C	0.074	0.072	0.073	0.074	0.072	0.071	0.068	0.070	0.071	0.072	0.074	0.074	0.074	0.071	0.071
		140°C	0.071	0.068	0.069	0.067	0.069	0.068	0.067	0.069	0.066	0.068	0.072	0.067	0.067	0.067	0.069
	Standard disk	30°C	0.065	0.066	0.065	0.065	0.065	0.066	0.066	0.066	0.065	0.066	0.066	0.065	0.065	0.064	0.065

[0205] As can be seen from Table 1, the lubricating oil compositions of Examples 1 to 11, which satisfy all the features of the present invention, have a friction coefficient of 0.098 or less with respect to the mirror-finished disk at an oil temperature of 30°C, and are thus excellent in the effect of reducing the friction coefficient.

[0206] On the other hand, it can be seen that the lubricating oil compositions of Comparative Examples 1 to 4 have a higher friction coefficient than the lubricating oil compositions of Examples 1 to 11.

Claims

1. A lubricating oil composition comprising a mineral base oil (A), a polymer (B) having a weight average molecular weight (Mw) of 100 to 15,000, and a molybdenum-based friction modifier (M), wherein the lubricating oil composition has a kinematic viscosity at 40°C of 35.0 mm²/s or less.
2. The lubricating oil composition according to claim 1, wherein the content of the polymer (B) is 0.1 to 5.0% by mass based on the total amount of the lubricating oil in terms of solid content.
3. The lubricating oil composition according to claim 1 or 2, wherein the polymer (B) is a polyolefin (B-1).
4. The lubricating oil composition according to any one of claims 1 to 3, wherein the weight average molecular weight (Mw) of the polymer (B) is 1,000 to 11,000.
5. The lubricating oil composition according to any one of claims 1 to 4, wherein the molybdenum-based friction modifier (M) comprises two or more selected from a binuclear molybdenum dithiocarbamate, a trinuclear molybdenum dithiocarbamate, and a molybdenum amine complex.
6. The lubricating oil composition according to any one of claims 1 to 5, wherein the content of the molybdenum-based friction modifier (M) is 50 to 2,000 ppm by mass in terms of molybdenum atom based on the total amount of the composition.
7. The lubricating oil composition according to any one of claims 1 to 6, which is used in an engine provided with a member having a maximum height roughness (Rz) of the surface of less than 0.45 µm.
8. The lubricating oil composition according to any one of claims 1 to 7, which is used in an automobile engine equipped with a hybrid mechanism or an idling stop mechanism.
9. A method for lubricating an engine, comprising lubricating an engine provided with a member having a maximum height roughness (Rz) of the surface of less than 0.45 µm using the lubricating oil composition according to any one of claims 1 to 7.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/007934

A. CLASSIFICATION OF SUBJECT MATTER

C10M 169/04(2006.01)i; *C10N 10/12*(2006.01)n; *C10N 30/06*(2006.01)n; *C10N 40/25*(2006.01)n; **C10M 133/04**(2006.01)i;
C10M 135/18(2006.01)i

FI: C10M169/04 ZHV; C10M135/18; C10M133/04; C10N10:12; C10N40:25; C10N30:06

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C10M101/00-177/00; C10N10/12; C10N30/06; C10N40/25

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 1971-2022
 Registered utility model specifications of Japan 1996-2022
 Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2020/203524 A1 (IDEMITSU KOSAN CO., LTD.) 08 October 2020 (2020-10-08) paragraphs [0007], [0060], [0068], [0071]-[0072], table 1, examples 1-9	1-6
Y	paragraphs [0007], [0060], [0068], [0071]-[0072], table 1, examples 1-9	1-9
Y	JP 2011-195734 A (IDEMITSU KOSAN CO., LTD.) 06 October 2011 (2011-10-06) paragraphs [0005], [0008], [0020]-[0026], [0029], [0037]-[0038], [0042], table 1, example 5	1-9
Y	WO 2018/070363 A1 (IDEMITSU KOSAN CO., LTD.) 19 April 2018 (2018-04-19) paragraph [0006], examples	7, 9
Y	JP 2007-23356 A (TOYOTA CENTRAL RES. & DEV. LAB., INC.) 01 February 2007 (2007-02-01) paragraph [0018], examples	7, 9
Y	JP 2005-98495 A (NISSAN MOTOR CO., LTD.) 14 April 2005 (2005-04-14) paragraph [0024], examples	7, 9

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

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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

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C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	JP 2020-158784 A (IDEMITSU KOSAN CO., LTD.) 01 October 2020 (2020-10-01) paragraphs [0160]-[0161]	8
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A	JP 2019-189668 A (EMG LUBRICANTS GK) 31 October 2019 (2019-10-31) entire text, all drawings	1-9
A	JP 2021-8540 A (IDEMITSU KOSAN CO., LTD.) 28 January 2021 (2021-01-28) entire text	1-9
A	JP 2020-139145 A (SANYO CHEM. IND. LTD.) 03 September 2020 (2020-09-03) entire text	1-9

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/007934

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JP 2011-195734 A	06 October 2011	US 2013/0029892 A1 paragraphs [0010], [0012], [0040]-[0047], [0051]-[0052], [0088]-[0094], [0096], table 1, example 5	
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JP 2021-8540 A	28 January 2021	(Family: none)	
JP 2020-139145 A	03 September 2020	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2019189668 A [0006]