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

(11) **EP 4 289 919 A1**

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

(43) Date of publication:
13.12.2023 Bulletin 2023/50

(21) Application number: **22749806.0**

(22) Date of filing: **04.02.2022**

(51) International Patent Classification (IPC):
C10M 141/08 *(2006.01)* ***C10N 10/04*** *(2006.01)*
C10N 10/12 *(2006.01)* ***C10N 30/06*** *(2006.01)*
C10N 30/08 *(2006.01)* ***C10N 40/25*** *(2006.01)*
C10M 133/56 *(2006.01)* ***C10M 139/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C10M 133/56; C10M 139/00; C10M 141/08;
C10N 2010/04; C10N 2010/12; C10N 2030/06;
C10N 2030/08; C10N 2040/25

(86) International application number:
PCT/JP2022/004403

(87) International publication number:
WO 2022/168935 (11.08.2022 Gazette 2022/32)

(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:
KH MA MD TN

(30) Priority: **05.02.2021 JP 2021017603**

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(54) LUBRICANT COMPOSITION

(57) There is provided a lubricating oil composition containing a base oil (A), a molybdenum-based friction modifier (B), a metal-based detergent (C), and a dispersant (D), in which the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D1), in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method, a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount of the dispersant (D), and a kinematic viscosity at 100°C is 9.3 mm^2/s or less. The lubricating oil composition has an excellent effect of reducing a friction coefficient while containing a molybdenum-based friction modifier and a succinimide compound.

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Description

Technical Field

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

Background Art

[0002] In recent years, in order to reduce an environmental load, vehicles such as automobiles are required to have improved fuel consumption reducing properties. As a method for improving the fuel consumption reducing properties, there is known a method of preventing an energy loss by decreasing the viscosity of a lubricating oil composition, reducing a stirring loss, and reducing viscosity resistance of an oil film under fluid lubrication.

[0003] On the other hand, as the viscosity of the lubricating oil composition decreases, the lubricating oil film becomes thinner and a friction loss due to metal contact increases, so that a higher metal friction-reducing action is required to further improve the fuel consumption reducing properties, and therefore, the use of a molybdenum-based friction modifier is accelerating.

[0004] In addition, the lubricating oil composition is required not only to have a reduced friction coefficient but also to maintain high-temperature detergency and dispersibility over a long period of time, and therefore, a detergent and a dispersant are also used in the lubricating oil composition.

[0005] As the dispersant, for example, it is known to use a succinimide compound (see, for example, PTL 1).

Citation List

Patent Literature

[0006] PTL 1: JP 2017-31405 A

Summary of Invention

Technical Problem

[0007] However, as a result of studies by the present inventors, it has been found that, in an environment where the temperature of the lubricating oil composition is high, the succinimide compound contained as a dispersant in the lubricating oil composition inhibits the friction-reducing action of the molybdenum-based friction modifier, and the molybdenum-based friction modifier may not exhibit an effect of reducing a friction coefficient.

[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 which has an excellent effect of reducing a friction coefficient while containing a molybdenum-based friction modifier and a succinimide compound.

Solution to Problem

[0009] The present inventors have made intensive studies and found that the above problem can be solved by a specific lubricating oil composition, and have thus completed the present invention.

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

[1] A lubricating oil composition containing:

a base oil (A);
a molybdenum-based friction modifier (B);
a metal-based detergent (C); and
a dispersant (D), in which
the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D 1),
a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method,
a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount (100 mass%) of the dispersant (D), and
a kinematic viscosity at 100°C is 9.3 mm^2/s or less.

Advantageous Effects of Invention

[0011] According to the present invention, it is possible to provide a lubricating oil composition which has an excellent effect of reducing a friction coefficient while containing a molybdenum-based friction modifier and a succinimide compound.

Description of Embodiments

[0012] In the present description, a lower limit value and an upper limit value described in a stepwise manner in a preferred numerical range (for example, a range of content or the like) can be independently combined. For example, from the description of the lower limit value of "preferably 10 or more, more preferably 30 or more, and even more preferably 40 or more" and the description of the upper limit value of "preferably 90 or less, more preferably 80 or less, and even more preferably 70 or less", a range obtained by combining the lower limit value and the upper limit value, which are independently selected, such as "10 or more and 70 or less", "30 or more and 70 or less", or "40 or more and 80 or less" may be selected as a preferred range. From the same description, it is also possible to select a range that simply specifies one of the lower limit value and the upper limit value, for example, "40 or more" or "70 or less". The same applies to preferred ranges that can be selected from the description, for example, "preferably 10 or more and 90 or less, more preferably 30 or more and 80 or less, and even more preferably 40 or more and 70 or less" and "preferably 10 to 90, more preferably 30 to 80, and even more preferably 40 to 70". In the present description, for example, the description of "10 to 90" in the description of the numerical range has the same meaning as "10 or more and 90 or less". The numerical values of "or more", "or less", "less than", and "more than" regarding the description of the numerical range can also be freely combined.
[0013] In the present description, for example, the term "(meth)acrylate" is used as a term indicating both "acrylate" and "methacrylate", and the same applies to other similar terms and similar notations.
[0014] In the present description, a "kinematic viscosity at 40°C" is also referred to as a "40°C kinematic viscosity". Similarly, a "kinematic viscosity at 100°C" is also referred to as a "100°C kinematic viscosity".

[Lubricating Oil Composition]

[0015] A lubricating oil composition according to the present embodiment contains a base oil (A), a molybdenum-based friction modifier (B), a metal-based detergent (C), and a dispersant (D), in which the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D1), in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method, a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount (100 mass%) of the dispersant (D), and a kinematic viscosity at 100°C is 9.3 mm^2/s or less.
[0016] The present inventors have made intensive studies to solve the above problem. As a result, it has been found that when the dispersant (D) in the lubricating oil composition contains the non-boron-modified polyisobutenyl succinic bisimide (D1) and the specific peak intensity in the IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by the FT-IR method satisfies a specific condition, the dispersant (D) is less likely to inhibit a friction-reducing action of the molybdenum-based friction modifier, and a lubricating oil composition in which the molybdenum-based friction modifier exhibits an effect of reducing a friction coefficient can be obtained.
[0017] Specifically, the present inventors have found the following.
[0018] In the IR spectrum, infrared absorption at 1705 cm^{-1} is caused by a C=O stretching vibration of a carbonyl group in an imide skeleton contained in the non-boron-modified polyisobutenyl succinic bisimide. The peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} is proportional to an amount of the carbonyl group in the imide skeleton.
[0019] In the IR spectrum, infrared absorption at 1390 cm^{-1} is caused by a bending vibration of a methyl group CH_3 at a terminal of a polyisobutenyl chain contained in the non-boron-modified polyisobutenyl succinic bisimide. The peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is proportional to an amount of the methyl group CH_3 at the terminal of the polyisobutenyl chain.
[0020] The ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of these peak intensities means a relative ratio of the imide skeleton containing a carbonyl group and being a polar moiety to the polyisobutenyl chain containing a methyl group and being a nonpolar moiety in the non-boron-modified polyisobutenyl succinic bisimide.
[0021] In the non-boron-modified polyisobutenyl succinic bisimide (D1) having a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of 7.5 or less, a ratio of the polar moiety to the nonpolar moiety in the compound is relatively small as compared with the compound having the ratio more than 7.5. Therefore, the present inventors have found that, in the lubricating oil composition containing the base oil (A) as a nonpolar solvent and the polar molybdenum-based friction modifier (B), the non-boron-modified polyisobutenyl succinic bisimide (D1) is less likely to inhibit the friction-reducing action of the

molybdenum-based friction modifier (B).

[0022] In addition, the present inventors have found that even when the dispersant (D) contains the non-boron-modified polyisobutenyl succinic bisimide (D1) having a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of 7.5 or less, a sufficient friction-reducing effect cannot be obtained when the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is less than 50 mass% based on the total amount (100 mass%) of the dispersant (D) (see Comparative Example 1 described later).

[0023] Therefore, the present inventors have found that the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is required to be 50 mass% or more based on the total amount (100 mass%) of the dispersant (D) in order to obtain a sufficient friction-reducing effect.

[0024] In the present invention, it is significant that the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is defined based on the total amount (100 mass%) of the dispersant (D), not based on the total amount (100 mass%) of the lubricating oil composition. This is because when the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) based on the total amount (100 mass%) of the dispersant (D) is different, the friction-reducing effect of the lubricating oil composition changes due to the influence of other dispersants, even when the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) based on the total amount (100 mass%) of the lubricating oil composition is the same.

[0025] Based on these findings, the present inventors have made further intensive studies and completed the present invention.

[0026] In the following description, the base oil (A), the molybdenum-based friction modifier (B), the metal-based detergent (C), and the dispersant (D) are also referred to as a component (A), a component (B), a component (C), and a component (D), respectively.

[0027] In the following description, the non-boron-modified polyisobutenyl succinic bisimide (D1), a non-boron-modified succinimide (D2) other than the non-boron-modified polyisobutenyl succinic bisimide (D1), and a boron-modified succinimide (D3) are also referred to as a component (D1), a component (D2), and a component (D3), respectively.

[0028] In the lubricating oil composition according to the present embodiment, a total content of the component (A), the component (B), the component (C), and the component (D) is preferably 70 mass% or more, more preferably 75 mass% or more, and even more preferably 80 mass% or more.

[0029] In the lubricating oil composition according to the present embodiment, an upper limit value of the total content of the component (A), the component (B), the component (C), and the component (D) may be 100 mass%. However, when the lubricating oil composition contains components other than the component (A), the component (B), the component (C), and the component (D), the upper limit value of the total content of the component (A), the component (B), the component (C), and the component (D) may be regulated in relation to the other components, and is preferably 95 mass% or less, more preferably 90 mass% or less, and even more preferably 85 mass% or less.

[0030] Hereinafter, each component contained in the lubricating oil composition according to the present embodiment will be described.

<Base Oil (A)>

[0031] The lubricating oil composition according to the present embodiment contains the base oil (A). As the base oil (A), one or more selected from a mineral oil and a synthetic oil used in related art as a base oil for a lubricating oil can be used without particular limitation.

[0032] Examples of the mineral oil include: atmospheric residues obtained by subjecting a crude oil, such as a paraffin base crude oil, an intermediate base crude oil, a naphthenic base crude oil to atmospheric distillation; distillates obtained by subjecting the atmospheric residue to distillation under a reduced pressure; and mineral oils obtained by subjecting the distillate to one or more refinement treatments, such as solvent deasphalting, solvent extraction, hydro-finishing, hydro-cracking, advanced hydro-cracking, solvent dewaxing, catalytic dewaxing, and hydroisomerized dewaxing.

[0033] Examples of the synthetic oil include: a poly-α-olefin, such as an α-olefin homopolymer or an α-olefin copolymer (for example, a copolymer of an α-olefin having 8 to 14 carbon atoms, such as an ethylene-α-olefin copolymer); an isoparaffin; various esters, such as a polyol ester and a dibasic acid ester; various ethers, such as a polyphenyl ether; a polyalkylene glycol; an alkylbenzene; an alkylnaphthalene; and a gas-to-liquids (GTL) base oil obtained by isomerizing a wax (GTL wax) produced from a natural gas by a Fischer-Tropsch method or the like.

[0034] The base oil used in the present embodiment is preferably a base oil classified into Group II or Group III of the base stock categories of the API (American Petroleum Institute), and more preferably a base oil classified into Group III.

[0035] As the base oil (A), one selected from mineral oils may be used alone, or two or more selected from mineral oils may be used in combination. In addition, one selected from synthetic oils may be used alone, or two or more selected from synthetic oils may be used in combination. Further, one or more mineral oils and one or more synthetic oils may be used in combination.

[0036] Upper limit values of a kinematic viscosity and a viscosity index of the base oil (A) are preferably in the following ranges from the viewpoint of improving fuel consumption reducing properties, and lower limit values thereof are preferably in the following ranges from the viewpoint of reducing a loss of the lubricating oil composition due to evaporation and ensuring oil film retention.

[0037] A kinematic viscosity at 40°C of the base oil (A) is preferably 2.0 mm^2/s to 100.0 mm^2/s, more preferably 2.0 mm^2/s to 80.0 mm^2/s, even more preferably 2.0 mm^2/s to 60.0 mm^2/s, still more preferably 2.0 mm^2/s to 40.0 mm^2/s, and even still more preferably 5.0 mm^2/s to 25.0 mm^2/s.

[0038] A kinematic viscosity at 100°C of the base oil (A) is preferably 2.0 mm^2/s to 20.0 mm^2/s, more preferably 2.0 mm^2/s to 10.0 mm^2/s, even more preferably 2.0 mm^2/s to 8.0 mm^2/s, and still more preferably 2.0 mm^2/s to 5.0 mm^2/s.

[0039] A viscosity index of the base oil (A) is preferably 80 or more, more preferably 90 or more, even more preferably 100 or more, still more preferably 105 or more, and even still more preferably 120 or more.

[0040] The kinematic viscosity at 40°C, the kinematic viscosity at 100°C, and the viscosity index can be measured or calculated in accordance with JIS K 2283:2000.

[0041] When the base oil (A) is a mixed base oil containing two or more base oils, the kinematic viscosity and the viscosity index of the mixed base oil are preferably within the above ranges.

[0042] In the lubricating oil composition according to the present embodiment, a content of the base oil (A) is not particularly limited, and is preferably 60 mass% to 99 mass%, more preferably 70 mass% to 95 mass%, and even more preferably 80 mass% to 93 mass%, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of more easily exhibiting the effect of the present invention.

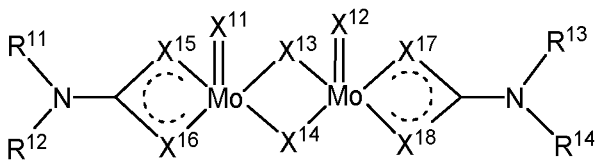
<Molybdenum-based Friction Modifier (B)>

[0043] The lubricating oil composition according to the present embodiment contains the molybdenum-based friction modifier (B). When the lubricating oil composition contains the molybdenum-based friction modifier (B), the friction-reducing action can be improved. In particular, the friction-reducing action can be effectively exhibited in an environment where the temperature of the lubricating oil composition is high.

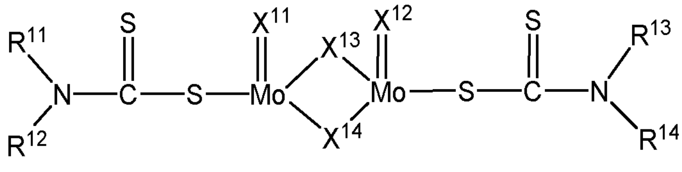
[0044] As the molybdenum-based friction modifier (B), any compound having a molybdenum atom can be used, and examples thereof include a molybdenum dithiocarbamate (MoDTC), a molybdenum dithiophosphate (MoDTP), and an amine salt of a molybdic acid. Among them, a molybdenum dithiocarbamate (MoDTC) and a molybdenum dithiophosphate (MoDTP) are preferred, and a molybdenum dithiocarbamate (MoDTC) is more preferred, from the viewpoint of reducing a metal-to-metal friction coefficient and obtaining excellent fuel consumption reducing properties.

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

[0046] Examples of the binuclear molybdenum dithiocarbamate include a compound represented by the following general formula (B-1) and a compound represented by the following general formula (B-2).



(B-1)



(B-2)

[0047] In the general formulae (B-1) and (B-2), R^{11} to R^{14} each independently represent a hydrocarbon group, and R^{11} to R^{14} may be the same as or different from each other.

[0048] X^{11} to X^{18} each independently represent an oxygen atom or a sulfur atom, and X^{11} to X^{18} may be the same as or different from each other. It should be noted that at least two of X^{11} to X^{18} in the formula (B-1) are sulfur atoms.

[0049] The number of carbon atoms in the hydrocarbon group which may be selected as R^{11} to R^{14} is preferably 6 to 22.

[0050] Examples of the hydrocarbon group which may be selected as R^{11} to R^{14} in the general formulae (B-1) and (B-2) include an alkyl group, an alkenyl group, a cycloalkyl group, an aryl group, an alkylaryl group, and an arylalkyl group.

[0051] 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.

[0052] 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.

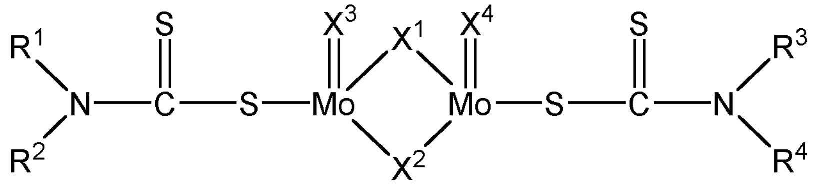
[0053] Examples of the cycloalkyl group include a cyclohexyl group, a dimethylcyclohexyl group, an ethylcyclohexyl group, a methylcyclohexylmethyl group, a cyclohexylethyl group, a propylcyclohexyl group, a butylcyclohexyl group, and a heptylcyclohexyl group.

[0054] Examples of the aryl group include a phenyl group, a naphthyl group, an anthracenyl group, a biphenyl group, and a terphenyl group.

[0055] Examples of the alkylaryl group include a tolyl group, a dimethylphenyl group, a butylphenyl group, a nonylphenyl group, and a dimethylnaphthyl group.

[0056] Examples of the arylalkyl group include a methylbenzyl group, a phenylmethyl group, a phenylethyl group, and a diphenylmethyl group.

[0057] Among them, a molybdenum dialkyldithiocarbamate represented by the following structural formula (B-3) is preferred.



(B-3)

[0058] [In the structural formula (B-3), R^1, R^2, R^3, and R^4 each independently represent an aliphatic hydrocarbon group having 4 to 22 carbon atoms. X^1 and X^2 are sulfur atoms, and X^3 and X^4 are oxygen atoms.]

[0059] It is preferable that R^1, R^2, R^3, and R^4 each independently include a short-chain substituent group which is an aliphatic hydrocarbon group having 4 to 12 carbon atoms or a long-chain substituent group which is an aliphatic hydrocarbon group having 13 to 22 carbon atoms.

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

[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 groups may be linear or branched. The number of carbon atoms in the aliphatic hydrocarbon group which may be selected as the short-chain substituent group is preferably 5 to 11, more preferably 6 to 10, and even more preferably 7 to 9, from the viewpoint of more easily exhibiting the effect of the present invention.

[0062] Examples of the aliphatic hydrocarbon group having 13 to 22 carbon atoms which may be selected as the long-chain substituent group include an alkyl group having 13 to 22 carbon atoms and an alkenyl group having 13 to 22 carbon atoms.

[0063] 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 eicosyl group, a heneicosyl 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 heneicosenyl group, and a docosenyl group. These groups may be linear or branched.

[0064] The number of carbon atoms in the aliphatic hydrocarbon group which may be selected as the long-chain substituent group is preferably 13 to 20, more preferably 13 to 16, and even more preferably 13 to 14, from the viewpoint of more easily exhibiting the effect of the present invention.

[0065] A molar ratio (the short-chain substituent group The long-chain substituent group) of the short-chain substituent group to the long-chain substituent group in all molecules of the molybdenum dialkyldithiocarbamate represented by the structural formula (1) is preferably 10:90 to 90:10, more preferably 30:70 to 70:30, and even more preferably 40:60 to 60:40.

[0066] Examples of the trinuclear molybdenum dithiocarbamate include a compound represented by the following general formula (B-4).

$$Mo_3S_kE_mL_nA_pQ_z \qquad (B\text{-}4)$$

[0067] In the general formula (B-4), 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, 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, and includes a nonstoichiometric value.

[0068] E's each independently represent an oxygen atom or a selenium atom, and for example, can substitute sulfur in cores described later.

[0069] L's each independently represent an anionic ligand having an organic group having a carbon atom, the total number of carbon atoms in the organic group in each ligand is 14 or more, and the ligands may be the same as or different from each other.

[0070] A's each independently represent an anion other than L.

[0071] Q's each independently represent an electron donating neutral compound and is present to fill an empty coordination in the trinuclear molybdenum compound.

[0072] In the lubricating oil composition according to the present embodiment, a content of the molybdenum-based friction modifier (B) is preferably 0.10 mass% or more and 5.0 mass% or less, more preferably 0.30 mass% or more and 3.0 mass% or less, and even more preferably 0.50 mass% or more and 1.5 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of reducing a metal-to-metal friction coefficient and obtaining excellent fuel consumption reducing properties.

[0073] In the lubricating oil composition according to the present embodiment, a content of a molybdenum atom derived from the molybdenum-based friction modifier (B) is preferably 0.01 mass% or more, more preferably 0.03 mass% or more, even more preferably 0.04 mass% or more, and still more preferably 0.05 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of improving the friction-reducing action.

[0074] The content of the molybdenum atom derived from the molybdenum-based friction modifier (B) is preferably 0.20 mass% or less, more preferably 0.15 mass% or less, even more preferably 0.12 mass% or less, and still more preferably 0.10 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of reducing a sulfated ash content.

<Metal-based Detergent (C)>

[0075] The lubricating oil composition according to the present embodiment contains the metal-based detergent (C). When the lubricating oil composition contains the metal-based detergent (C), high-temperature detergency and dispersibility can be improved.

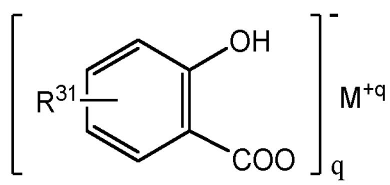
[0076] Examples of the metal-based detergent (C) include an organic acid metal salt compound containing a metal atom selected from an alkali metal and an alkaline earth metal, and specific examples thereof include a metal salicylate, a metal phenate, and a metal sulfonate each containing a metal atom selected from an alkali metal and an alkaline earth metal.

[0077] In the present description, the term "alkali metal" refers to lithium, sodium, potassium, rubidium, cesium, and francium.

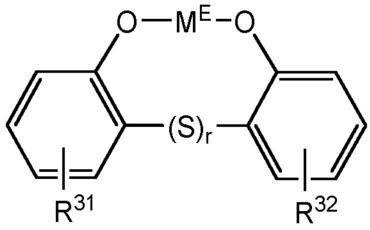
[0078] The "alkaline earth metal" refers to beryllium, magnesium, calcium, strontium, and barium.

[0079] The metal atom contained in the metal-based detergent (C) is preferably sodium, calcium, magnesium, or barium, and more preferably calcium or magnesium, from the viewpoint of improving high-temperature detergency.

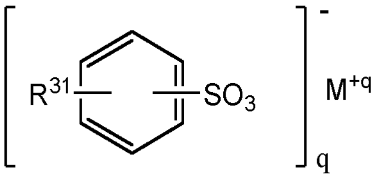
[0080] The metal salicylate is preferably a compound represented by the following general formula (c-1), the metal phenate is preferably a compound represented by the following general formula (c-2), and the metal sulfonate is preferably a compound represented by the following general formula (c-3).



(c-1)



(c-2)



(c-3)

[0081] In the general formulae (c-1) to (c-3), M is a metal atom selected from an alkali metal and an alkaline earth metal, and is preferably sodium, calcium, magnesium, or barium, and more preferably calcium or magnesium. M^E is an alkaline earth metal, and is preferably calcium, magnesium, or barium, and more preferably calcium or magnesium, q is a valence of M, and is 1 or 2. R^{31} and R^{32} each independently represent 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 is preferably an integer of 0 to 3.

[0082] 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.

[0083] These may be used alone or may be used in combination with two or more thereof. Among them, one or more selected from calcium salicylate, calcium phenate, calcium sulfonate, magnesium salicylate, magnesium phenate, and magnesium sulfonate are preferred, from the viewpoint of improving high-temperature detergency and dispersibility and the viewpoint of solubility in the base oil.

[0084] The metal-based detergent (C) may be any of a neutral salt, a basic salt, an overbased salt, and a mixture thereof.

[0085] A base number of the metal-based detergent (C) is preferably 0 mgKOH/g to 600 mgKOH/g.

[0086] When the metal-based detergent is a basic salt or an overbased salt, the base number of the metal-based detergent is preferably 10 mgKOH/g to 600 mgKOH/g, and more preferably 20 mgKOH/g to 500 mgKOH/g.

[0087] In the present description, the term "base number" refers to a base number measured by a perchloric acid method in accordance with section 7 of JIS K 2501:2003 "Petroleum products and lublicants-Determination of neutralization number".

[0088] In the lubricating oil composition according to the present embodiment, a content of the metal-based detergent (C) is preferably 0.01 mass% to 10 mass%, more preferably 0.1 mass% to 5.0 mass%, even more preferably 0.2 mass% to 3.0 mass%, and still more preferably 0.3 mass% to 2.0 mass%, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of more easily exhibiting the effect of the present invention.

[0089] The metal-based detergent (C) may be used alone or may be used in combination of two or more thereof. A suitable total content in the case of using two or more thereof is also the same as the content described above.

[0090] In the lubricating oil composition according to the present embodiment, when the metal atom contained in the metal-based detergent (C) is calcium, a content of a calcium atom derived from the metal-based detergent (C) is preferably 0.05 mass% or more, more preferably 0.10 mass% or more, and even more preferably 0.11 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of high-temperature detergency and dispersibility.

[0091] The content of the calcium atom derived from the metal-based detergent (C) is preferably 0.50 mass% or less, more preferably 0.40 mass% or less, even more preferably 0.30 mass% or less, still more preferably 0.20 mass% or less, even still more preferably 0.15 mass% or less, and yet still more preferably 0.13 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of reducing a sulfated ash content and the viewpoint of preventing LSPI (abnormal combustion).

[0092] In the lubricating oil composition according to the present embodiment, when the metal atom contained in the metal-based detergent (C) is magnesium, a content of a magnesium atom derived from the metal-based detergent (C) is preferably 0.02 mass% or more, more preferably 0.03 mass% or more, and even more preferably 0.04 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of high-temperature detergency and dispersibility.

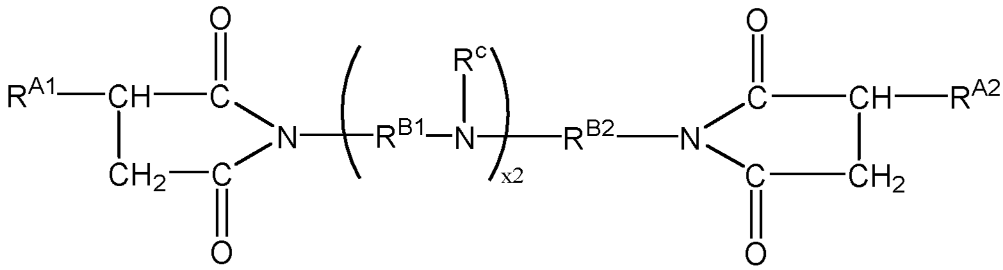
[0093] The content of the magnesium atom derived from the metal-based detergent (C) is preferably 0.07 mass% or less, more preferably 0.06 mass% or less, and even more preferably 0.05 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of reducing a sulfated ash content and the viewpoint of preventing LSPI (abnormal combustion).

<Dispersant (D)>

[0094] The lubricating oil composition according to the present embodiment contains the dispersant (D). The dispersant (D) contains the non-boron-modified polyisobutenyl succinic bisimide (D1). When the lubricating oil composition contains the dispersant (D) containing the non-boron-modified polyisobutenyl succinic bisimide (D1), high-temperature detergency and dispersibility can be maintained over a long period of time.

<<Non-boron-modified Polyisobutenyl Succinic Bisimide (D1)>>

[0095] The dispersant (D) contains the non-boron-modified polyisobutenyl succinic bisimide (D1).
[0096] When the lubricating oil composition according to the present embodiment does not contain the non-boron-modified polyisobutenyl succinic bisimide (D1), it is not possible to maintain the high-temperature detergency and dispersibility for a long period of time.
[0097] As the non-boron-modified polyisobutenyl succinic bisimide (D1), a non-boron-modified succinimide compound (D1y) represented by the following general formula (d-1y) is preferred.



(d-1y)

[0098] In the general formula (d-1y), R^{A1} and R^{A2} each independently represent a polyisobutenyl group.
[0099] A mass average molecular weight (Mw) of the polyisobutenyl group is preferably 500 to 4,000, more preferably 900 to 3,000, even more preferably 1,300 to 2,800, and still more preferably 1,800 to 2,600.
[0100] In the present invention, the mass average molecular weight (Mw) of the polyisobutenyl group can be evaluated as a mass average molecular weight (Mw) in terms of standard polystyrene by measuring, for example, a polyolefin, which is a generation source of the alkenyl group, using a GPC apparatus (apparatus name: HLC-8220, manufactured by Tosoh Corporation) with columns (product name: TSK gel GMH-XL, two, product name: G2000H-XL, one, manufactured by Tosoh Corporation) attached under conditions of a detector: a refractive index detector, a measurement temperature: 40°C, a mobile phase: tetrahydrofuran, a flow rate: 1.0 mL/min, and a concentration of 0.5 mg/mL.
[0101] As another method, a value obtained by subtracting, from a mass average molecular weight of the non-boron-modified polyisobutenyl succinic bisimide (D1) measured by the same measurement method as described above, a theoretical molecular weight of the corresponding structure other than the polyisobutenyl group, and then dividing the resulting value by the number of polyisobutenyl groups contained in one molecule may be determined as the mass average molecular weight (Mw) of the polyisobutenyl group.
[0102] In the general formula (d-1y), R^{B1} and R^{B2} each independently represent an alkylene group having 2 to 5 carbon atoms.
[0103] Examples of the alkylene group include a methylene group, an ethylene group, a trimethylene group, various butylene groups, and various pentylene groups. In the present description, the term "various" in various butylene groups and the like is meant to include linear groups, branched groups, and isomers thereof.
[0104] In the general formula (d-1y), R^C represents a hydrogen atom, an alkyl group having 1 to 10 carbon atoms, or a group represented by $-(AO)_n-H$ (where A represents an alkylene group having 2 to 4 carbon atoms, and n represents an integer of 1 to 10).
[0105] Examples of the alkyl group include a linear or branched alkyl group, such as 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 1,1-dimethylhexyl group, a 2-ethylhexyl group, a nonyl group, a 1,1-dimethylheptyl group, and a decyl group.
[0106] Examples of the alkylene group having 2 to 4 carbon atoms and represented by A include an ethylene group, a trimethylene group, and various butylene groups, and an ethylene group is preferred.
[0107] n is an integer of 1 to 10, preferably an integer of 1 to 5, and more preferably an integer of 1 to 3.

[0108] In the general formula (d-1y), x2 is an integer of 1 to 10, preferably an integer of 3 to 7, and more preferably 5 or 6.

[0109] As the non-boron-modified polyisobutenyl succinic bisimide (D1), a non-boron-modified succinimide compound (D1x) may be used alone or in combination of plural kinds thereof.

[0110] The non-boron-modified polyisobutenyl succinic bisimide (D1) can be produced, for example, by reacting an isobutenyl succinic anhydride obtained by a reaction between polyisobutylene and maleic anhydride with a polyamine to prepare an alkenyl succinimide having an active amine hydrogen (a compound in which R^c in the general formula (d-1y) is a hydrogen atom). Alternatively, the non-boron-modified polyisobutenyl succinic bisimide (D1) can be produced by substituting at least a part of the active amine hydrogen with the group represented by R^c.

[0111] Examples of the polyamine include: single diamines such as ethylenediamine, propylenediamine, butylenediamine, and pentylenediamine; polyalkylene polyamines such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, di(methylethylene)triamine, dibutylenetriamine, tributylenetetramine, and pentapentylenehexamie; and piperazine derivatives such as aminoethylpiperazine.

[0112] For the substitution reaction of the active amine hydrogen, for example, a known method can be used, and examples thereof include a method of reacting an alkenyl succinimide compound having the active amine hydrogen with an alkyl halide giving R^c in the general formula (d-1y).

[0113] In the IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by the FT-IR method, the ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of the peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to the peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less.

[0114] When the ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] is more than 7.5, the molybdenum-based friction modifier (B) cannot sufficiently exhibit the friction-reducing action.

[0115] The ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] is preferably 5.0 or more and 7.5 or less, more preferably 6.0 or more and 7.3 or less, and even more preferably 6.5 or more and 7.1 or less, from the viewpoint of further improving the friction-reducing action of the molybdenum-based friction modifier (B).

[0116] The IR spectrum can be determined by a measuring instrument using the FT-IR method under known conditions. Specifically, the measurement can be performed by a method described in Examples described later.

[0117] A content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more, preferably 50 mass% or more and 95 mass% or less, more preferably 63 mass% or more and 85 mass% or less, and even more preferably 65 mass% or more and 80 mass% or less, based on the total amount (100 mass%) of the dispersant (D). When the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is less than 50 mass% based on the total amount (100 mass%) of the dispersant (D), a sufficient friction-reducing effect cannot be obtained.

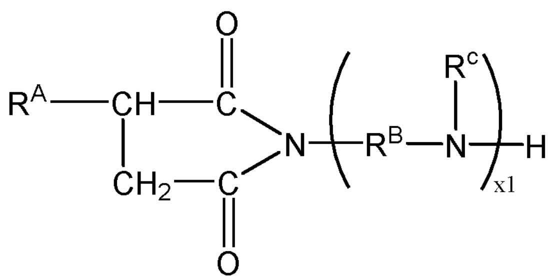
[0118] In the lubricating oil composition according to the present embodiment, the content of the component (D1) is preferably 0.10 mass% or more and 4.0 mass% or less, more preferably 1.5 mass% or more and 3.0 mass% or less, and even more preferably 1.6 mass% or more and 2.0 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of further improving the friction-reducing action.

<<Non-boron-modified succinimide (D2) Other than Component (D1)>>

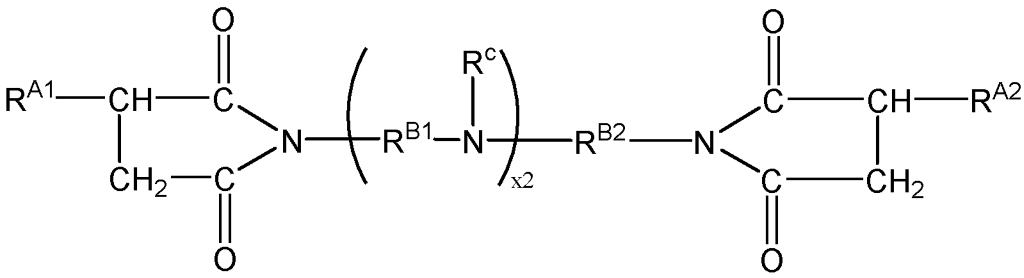
[0119] The dispersant (D) may further contain the non-boron-modified succinimide (D2) other than the component (D1).

[0120] In the case where the dispersant (D) does not contain the component (D1), the molybdenum-based friction modifier (B) cannot sufficiently exhibit the friction-reducing action even when the dispersant (D) contains the non-boron-modified succinimide (D2) other than the component (D1).

[0121] The non-boron-modified succinimide (D2) other than the component (D1) is preferably one or more non-boron-modified succinimide compounds (D2z) selected from a succinic monoimide (D2x) represented by the following general formula (d-2x) and a succinic bisimide (D2y) represented by the following general formula (d-2y).



(d-2x)



(d-2y)

[0122] In the general formulae (d-2x) and (d-2y), R^A, R^{A1}, and R^{A2} each independently represent an alkenyl group.

[0123] Examples of the alkenyl group include a polybutenyl group, a polyisobutenyl group, and an ethylene-propylene copolymer. Among them, a polybutenyl group and a polyisobutenyl group are preferred, and a polyisobutenyl group is more preferred.

[0124] A mass average molecular weight (Mw) of the alkenyl group is preferably 500 to 4,000, more preferably 900 to 3,000, even more preferably 1,300 to 2,800, and still more preferably 1,800 to 2,600.

[0125] In the present invention, the mass average molecular weight (Mw) of the alkenyl group can be determined by the method described in the component (D1).

[0126] In the general formulae (d-2x) and (d-2y), R^B, R^{B1}, and R^{B2} each independently represent an alkylene group having 2 to 5 carbon atoms.

[0127] Examples of the alkylene group include a methylene group, an ethylene group, a trimethylene group, various butylene groups, and various pentylene groups. In the present description, the term "various" in various butylene groups and the like is meant to include linear groups, branched groups, and isomers thereof.

[0128] In the general formulae (d-2x) and (d-2y), R^C represents a hydrogen atom, an alkyl group having 1 to 10 carbon atoms, or a group represented by $-(AO)_n-H$ (where A represents an alkylene group having 2 to 4 carbon atoms, and n represents an integer of 1 to 10).

[0129] Examples of the alkyl group include a linear or branched alkyl group, such as 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 1,1-dimethylhexyl group, a 2-ethylhexyl group, a nonyl group, a 1,1-dimethylheptyl group, and a decyl group.

[0130] Examples of the alkylene group having 2 to 4 carbon atoms and represented by A include an ethylene group, a trimethylene group, and various butylene groups, and an ethylene group is preferred.

[0131] n is an integer of 1 to 10, preferably an integer of 1 to 5, and more preferably an integer of 1 to 3.

[0132] In the general formula (d-2x), x1 is an integer of 1 to 10, preferably an integer of 2 to 5, and more preferably 3 or 4.

[0133] In the general formula (d-2y), x2 is an integer of 1 to 10, preferably an integer of 3 to 7, and more preferably 5 or 6.

[0134] As the component (D2), the succinic monoimide (D2x) may be used alone or in combination of plural kinds thereof. As the component (D2), the succinic bisimide (D2x) may be used alone or in combination of plural kinds thereof. Further, one or more succinic monoimides (D2x) and one or more succinic bisimides (D2x) may be used in combination.

[0135] The non-boron-modified succinimide compound (D2x) can be produced, for example, by reacting an alkenyl succinic anhydride obtained by a reaction between a polyolefin and maleic anhydride with a polyamine to prepare an alkenyl succinicimide having an active amine hydrogen (a compound in which R^c in the general formula (d-2x) or the general formula (d-2y) is a hydrogen atom). Alternatively, the non-boron-modified succinimide compound (D2x) can be produced by substituting at least a part of the active amine hydrogen with the group represented by R^c.

[0136] Examples of the polyolefin include a polymer obtained by polymerizing one or more selected from α-olefins each having 2 to 8 carbon atoms, and a copolymer of isobutene and 1-butene is preferred.

[0137] Examples of the polyamine include: single diamines such as ethylenediamine, propylenediamine, butylenediamine, and pentylenediamine; polyalkylene polyamines such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, di(methylethylene)triamine, dibutylenetriamine, tributylenetetramine, and pentapentylenehexamie; and piperazine derivatives such as aminoethylpiperazine.

[0138] The substitution reaction of the active amine hydrogen may be performed by a known method, and examples of the method include a method of reacting an alkenyl succinimide compound having the active amine hydrogen with an alkyl halide giving R^c in the general formulae (d-2x) and (d-2y).

[0139] In the lubricating oil composition according to the present embodiment, a content of the component (D2) is preferably 0.10 mass% or more and 2.0 mass% or less, more preferably 0.30 mass% or more and 1.5 mass% or less, and even more preferably 0.50 mass% or more and 1.0 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of maintaining high-temperature detergency.

[0140] A ratio [(D 1)/(D2)] of the content of the component (D1) to the content of the component (D2) is preferably 1 or more, and more preferably 2 or more in terms of mass ratio, from the viewpoint of further improving the friction-reducing action.

<<Boron-modified Succinimide (D3)>>

[0141] The dispersant (D) may further contain the boron-modified succinimide (D3).
[0142] In the case where the dispersant (D) does not contain the component (D1), the molybdenum-based friction modifier (B) cannot exhibit the friction-reducing action even when the dispersant (D) contains the boron-modified succinimide (D3).
[0143] On the other hand, in the lubricating oil composition according to the present embodiment, when the dispersant (D) contains the component (D1) and the component (D3), the effect of maintaining high-temperature detergency and dispersibility over a long period of time can be more easily exhibited.
[0144] The boron-modified succinimide (D3) is preferably one or more selected from a boron-modified product of the non-boron-modified polyisobutenyl succinic bisimide (D1) and a boron-modified product of the non-boron-modified succinimide (D2).
[0145] The component (D3) is preferably a boron-modified product of one or more non-boron-modified succinimide compounds (D2z) selected from the succinic monoimide (D2x) represented by the general formula (d-2x) and the succinic bisimide (D2y) represented by the general formula (d-2y).
[0146] In the lubricating oil composition according to the present embodiment, a content of the component (D3) is preferably 0.10 mass% or more and 3.0 mass% or less, more preferably 0.20 mass% or more and 2.0 mass% or less, and still more preferably 0.20 mass% or more and 1.5 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of maintaining high-temperature detergency.
[0147] A content of a boron atom derived from the boron-modified succinimide (D3) is preferably 0.03 mass% or less, and more preferably 0.001 mass% or more and 0.02 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition. When the content of the boron atom derived from the boron-modified succinimide (D3) is 0.03 mass% or less, an increase in the kinematic viscosity at 40°C can be prevented, and thus fuel consumption reducing properties can be improved.
[0148] A ratio [(D1)/(D3)] of the content of the component (D1) to the content of the component (D3) is preferably 1 or more, more preferably 8 or more, even more preferably 9 or more, and still more preferably 11 or more in terms of mass ratio, from the viewpoint of further improving the friction-reducing action.
[0149] A ratio of a content of a nitrogen atom derived from the non-boron-modified polyisobutenyl succinic bisimide (D1) to the content of the boron atom derived from the boron-modified succinimide (D3) is preferably 1 or more, more preferably 3 or more, and even more preferably 4 or more in terms of mass ratio, from the viewpoint of further improving the friction-reducing action.

[Content of Dispersant (D)]

[0150] In the lubricating oil composition according to the present embodiment, the content of the dispersant (D) is preferably 0.10 mass% or more and 5.0 mass% or less, more preferably 2.60 mass% or more and 4.0 mass% or less, and even more preferably 3.2 mass% or more and 3.6 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of maintaining high-temperature detergency.
[0151] A content of a nitrogen atom derived from the total dispersant (D) is preferably 0.01 mass% or more, and more preferably 0.02 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of maintaining high-temperature detergency and dispersibility over a long period of time. From the viewpoint of low viscosity, the content of the nitrogen atom derived from the total dispersant (D) is preferably 0.10 mass% or less, more preferably 0.07 mass% or less, even more preferably 0.06 mass% or less, still more preferably 0.05 mass% or less, and even still more preferably 0.04 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.
[0152] The content of the nitrogen atom can be measured in accordance with JIS K 2609:1998.
[0153] A ratio [(D1)/(B)-Mo] of the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) to a content of a molybdenum atom derived from the molybdenum-based friction modifier (B) is, in terms of mass ratio, preferably 15 or more and 90 or less, more preferably 20 or more and 80 or less, even more preferably 30 or more and 70 or less, and still more preferably 40 or more and 60 or less, from the viewpoint of improving the friction-reducing action and maintaining high-temperature detergency.

<Other Components>

[0154] If necessary, the lubricating oil composition according to the present embodiment may contain other components than the above components as long as the effects of the present invention are not impaired.
[0155] Examples of additives as the other components include a pour point depressant, an antioxidant, an anti-wear agent, a friction modifier other than the molybdenum-based friction modifier (B), an extreme pressure agent, a viscosity

index improver, a rust inhibitor, an anti-foaming agent, an oiliness improver, a metal deactivator, and a demulsifier.
[0156] These may be used alone or may be used in combination with two or more thereof.

-Pour Point Depressant-

[0157] Examples of the pour point depressant include an ethylene-vinyl acetate copolymer, a condensate of a chlorinated paraffin and naphthalene, a condensate of a chlorinated paraffin and phenol, a polymethacrylate-based pour point depressant (a PMA-based pour point depressant; a polyalkyl (meth)acrylate, and the like), a polyvinyl acetate, polybutene, and a polyalkylstyrene. A polymethacrylate-based pour point depressant is preferably used.
[0158] These may be used alone or may be used in combination with two or more thereof.

-Antioxidant-

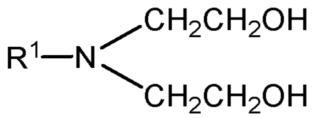
[0159] Examples of the antioxidant include an amine-based antioxidant and a phenol-based antioxidant.
[0160] Examples of the amine-based antioxidant include diphenylamine-based antioxidants such as diphenylamine and an alkylated diphenylamine having an alkyl group having 3 to 20 carbon atoms, and naphthylamine-based antioxidants 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.
[0161] Examples of the phenol-based antioxidant include monophenol-based antioxidants 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, diphenol-based antioxidants such as 4,4'-methylenebis(2,6-di-tert-butylphenol) and 2,2'-methylenebis(4-ethyl-6-tert-butylphenol), and hindered phenol-based antioxidants.
[0162] These may be used alone or may be used in combination with two or more thereof.

-Anti-wear Agent-

[0163] Examples of the anti-wear agent include: zinc-containing compounds such as a 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 an amine salt or a metal salt thereof; and sulfur- and phosphorus-containing anti-wear agents such as thiophosphite esters, thiophosphate esters, thiophosphonate esters, and an amine salt or a metal salt thereof.
[0164] Among them, a zinc dialkyldithiophosphate (ZnDTP) is preferred.
[0165] These may be used alone or may be used in combination with two or more thereof.

-Friction Modifier Other than Component (B)-

[0166] The lubricating oil composition according to the present embodiment may contain a friction modifier other than the component (B).
[0167] The component (B) is excellent in effectively exhibiting the friction-reducing action in an environment where the temperature of the lubricating oil composition is high, and when the lubricating oil composition contains a friction modifier other than the component (B), the friction-reducing action can be effectively exhibited even in an environment where the temperature of the lubricating oil composition is low.
[0168] Examples of the friction modifier other than the molybdenum-based friction modifier (B) include ash-free friction modifiers such as an aliphatic amine, a fatty acid ester, a fatty acid amide, a fatty acid, an aliphatic alcohol, and an aliphatic ether, fats and oils, an amine, an amide, a sulfurized ester, a phosphate ester, a phosphite ester, and an amine salt of a phosphate ester.
[0169] These may be used alone or may be used in combination with two or more thereof.
[0170] Here, as the friction modifier other than the component (B), an aliphatic amine is preferred, and among the aliphatic amine, an aliphatic amine having at least one alkyl group or alkenyl group having 2 to 30 carbon atoms in a molecule thereof is preferred.
[0171] Among the aliphatic amine having at least one alkyl group or alkenyl group having 2 to 30 carbon atoms in a molecule thereof, a diethanolamine compound represented by the following general formula (5) is preferred.



(5)

[0172] In the general formula (5), R^1 is a monovalent aliphatic hydrocarbon group having 12 to 30 carbon atoms. Preferred examples of the aliphatic hydrocarbon group having 12 to 30 carbon atoms and represented by R^1 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 even more preferably 16 to 20.

[0173] Examples of the linear or branched alkyl group having 12 to 30 carbon atoms include various dodecyl groups such as an n-dodecyl group, an isododecyl group, a sec-dodecyl group, a tert-dodecyl group, and a neododecyl group (hereinafter, a functional group having a predetermined number of carbon atoms and including a linear group, a branched group, and an isomer thereof may be abbreviated as "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 eicosyl groups, various heneicosyl 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.

[0174] 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 heneicosenyl groups, various docosenyl groups, various tricosenyl groups, various tetracosenyl groups, various pentacosenyl groups, various hexacosenyl groups, various heptacosenyl groups, various octacosenyl groups, various nonacosenyl groups, and various triaconyl groups.

[0175] Among them, in consideration of the effect of improving durability, preferred are various hexadecyl groups, various heptadecyl groups, and various octadecyl groups which are alkyl groups having 16 to 18 carbon atoms, various hexadecenyl groups, various heptadecenyl groups, and various octadecenyl groups, which are alkenyl groups having 16 to 18 carbon atoms, more preferred are various hexadecyl groups, various octadecyl groups, and various octadecenyl groups, and even more preferred are an n-hexadecyl group (palmityl group), an n-octadecyl group (stearyl group), and an n-octadecenyl group (oleyl group).

[0176] Preferred specific examples of the diethanolamine compound represented by the general formula (5) include one or more compounds selected from stearyl diethanolamine (in the general formula (5), R^1 is an n-octadecyl group (stearyl group)), oleyl diethanolamine (in the general formula (5), R^1 is an n-octadecenyl group (oleyl group)), and palmityl diethanolamine (in the general formula (5), R^1 is an n-hexadecyl group (palmityl group)). Among them, oleyl diethanolamine is preferred.

[0177] These may be used alone or may be used in combination with two or more thereof.

-Extreme Pressure Agent-

[0178] Examples of the extreme pressure agent include sulfur-based extreme pressure agents such as sulfides, sulfoxides, sulfones, and thiophosphinates, halogen-based extreme pressure agents such as a chlorinated hydrocarbon, and organic metal-based extreme pressure agents. Among the anti-wear agent described above, a compound having a function as an extreme pressure agent can also be used.

[0179] These may be used alone or may be used in combination with two or more thereof.

-Viscosity Index Improver-

[0180] Examples of the viscosity index improver include polymers such as a non-dispersant-type poly(meth)acrylate, a dispersant-type poly(meth)acrylate, a star polymer, an olefin-based copolymer (for example, an ethylene-propylene copolymer), a dispersant-type olefin-based copolymer, and a styrene-based copolymer (for example, a styrene-diene copolymer and a styrene-isoprene copolymer). Among them, a polymethacrylate and a star polymer are preferred.

[0181] These may be used alone or may be used in combination with two or more thereof.

[0182] A mass average molecular weight (Mw) of the viscosity index improver is preferably 10,000 to 1,000,000, preferably 15,000 to 800,000, and more preferably 200,000 to 700,000, and is appropriately set depending on the type of the polymer.

[0183] In the present description, the mass average molecular weight (Mw) of each component is a value in terms of standard polystyrene determined by gel permeation chromatography (GPC).

[0184] A permanent shear stability index (PSSI) of the viscosity index improver is preferably 40.0 or less, more preferably 35.0 or less, and even more preferably 30.0 or less.

[0185] The lower limit value of the SSI of the viscosity index improver is not particularly limited, and is generally 0.1 or more, preferably 0.2 or more, and more preferably 0.5 or more, from the viewpoint of stable presence of the viscosity index improver.
[0186] In the present description, the permanent shear stability index (PSSI) of the viscosity index improver is a value calculated in accordance with ASTM D6022-06, which indicates, in percentage, a decrease in viscosity due to shearing caused by a resin component in the viscosity index improver. More specifically, the PSSI is a value calculated according to the following calculation formula.

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

[0187] In the above calculation formula, Kv_0 represents a value of a kinematic viscosity at 100°C of a sample oil obtained by diluting a viscosity index improver containing a resin component with a mineral oil, and Kv_1 represents a value of a kinematic viscosity at 100°C after passing the sample oil obtained by diluting the viscosity index improver containing the resin component with the mineral oil through a high-shear diesel injector for 30 cycles according to the procedures of ASTM D6278. Kv_{oil} represents a value of a kinematic viscosity at 100°C of a mineral oil used for diluting the viscosity index improver.

-Rust Inhibitor-

[0188] Examples of the rust inhibitor include a fatty acid, an alkenyl succinic acid half ester, a fatty acid soap, an alkyl sulfonate salt, a polyhydric alcohol fatty acid ester, a fatty acid amine, an oxidized paraffin, and an alkyl polyoxyethylene ether.
[0189] These may be used alone or may be used in combination with two or more thereof.

-Anti-foaming Agent-

[0190] Examples of the anti-foaming agent include silicone oils such as a dimethylpolysiloxane, fluorosilicone oils, and fluoroalkyl ethers.
[0191] These may be used alone or may be used in combination with two or more thereof.

-Oiliness Improver-

[0192] 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 a dimer acid and a 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 such as glycerin or sorbitol and an aliphatic saturated or unsaturated monocarboxylic acid.

-Metal Deactivator-

[0193] 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.
[0194] These may be used alone or may be used in combination with two or more thereof.

-Demulsifier-

[0195] Examples of the demulsifier include: an anionic surfactant such as a castor oil sulfate ester salt and a petroleum sulfonate salt; a cationic surfactant such as a quaternary ammonium salt and imidazolines; a polyalkylene glycol-based nonionic surfactant such as a polyoxyethylene alkyl ether, a polyoxyethylene alkyl phenyl ether, and a polyoxyethylene alkyl naphthyl ether; a polyoxyalkylene polyglycol and an ester of a dicarboxylic acid thereof and an alkylene oxide adduct of an alkylphenol-formaldehyde polycondensate.
[0196] These may be used alone or may be used in combination with two or more thereof.
[0197] A content of the other components described above can be properly regulated within the range where the

effects of the present invention are not impaired, and the content of each of the other components is generally 0.001 mass% to 15 mass%, preferably 0.005 mass% to 10 mass%, more preferably 0.01 mass% to 7 mass%, and even more preferably 0.03 mass% to 5 mass%, based on the total amount (100 mass%) of the lubricating oil composition.

[0198] In the present description, additives as the other components may be blended with other components in the form of a solution diluted and dissolved in a part of the base oil (A) in consideration of handling properties, solubility in the base oil (A), and the like. In such a case, in the present description, the above-described content of the additives as the other components means a content in terms of an active component (in terms of a resin component) excluding the diluent oil.

[Physical Properties of Lubricating Oil Composition]

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

[0199] A kinematic viscosity at 40°C of the lubricating oil composition according to the present embodiment is preferably 2.0 mm^2/s or more and 150.0 mm^2/s or less, more preferably 2.0 mm^2/s or more and 100.0 mm^2/s or less, even more preferably 2.0 mm^2/s or more and 60.0 mm^2/s or less, still more preferably 2.0 mm^2/s or more and 40.0 mm^2/s or less, and even still more preferably 2.0 mm^2/s or more and 30.0 mm^2/s or less, from the viewpoint of improving fuel consumption reducing properties for the upper limit value and from the viewpoint of reducing a loss of the lubricating oil composition due to evaporation and ensuring oil film retention for the lower limit value.

[0200] A kinematic viscosity at 100°C of the lubricating oil composition according to the present embodiment is preferably 2.0 mm^2/s or more, more preferably 3.0 mm^2/s or more, even more preferably 4.1 mm^2/s or more, and still more preferably 4.5 mm^2/s or more. The kinematic viscosity at 100°C of the lubricating oil composition according to the present embodiment is 9.3 mm^2/s or less, preferably 9.0 mm^2/s or less, more preferably 8.5 mm^2/s or less, even more preferably 7.5 mm^2/s or less, still more preferably 7.1 mm^2/s, even still more preferably 6.1 mm^2/s or less, and yet still more preferably 5.8 mm^2/s or less. When the kinematic viscosity at 100°C is within the above range, it is easier to ensure fuel consumption reducing properties.

[0201] A viscosity index of the lubricating oil composition according to the present embodiment is preferably 110 or more, more preferably 120 or more, even more preferably 130 or more, and still more preferably 135 or more. When the viscosity index is within the above range, a change in viscosity due to the temperature becomes small.

[0202] The kinematic viscosity at 40°C, the kinematic viscosity at 100°C, and the viscosity index can be measured or calculated in accordance with JIS K 2283:2000.

<HTHS Viscosity at 150°C>

[0203] A high-temperature high-shear viscosity (HTHS viscosity) is a viscosity measured under conditions of a high temperature (150°C) and a shear rate of 10^6 S^{-1}.

[0204] An HTHS viscosity at 150°C (150°C HTHS viscosity) of the lubricating oil composition according to the present embodiment is preferably 1.0 mPa•s or more and 2.9 mPa•s or less, more preferably 1.3 mPa•s or more and 2.6 mPa•s or less, even more preferably 1.5 mPa•s or more and 2.3 mPa•s or less, still more preferably 1.7 mPa•s or more and 2.0 mPa•s or less, and even still more preferably 1.8 mPa•s or more and 1.9 mPa•s or less, from the viewpoint of fuel consumption reducing properties.

[0205] When the HTHS viscosity at 150°C is within the above range, the viscosity resistance of the lubricating oil composition is small, the energy loss is also small, and thus it is easier to improve fuel consumption reducing properties.

[0206] The HTHS viscosity at 150°C can be measured or calculated in accordance with JPI-5S-36-03.

<Sulfated Ash Content>

[0207] The sulfated ash content in the lubricating oil composition according to the present embodiment is preferably 1.0 mass% or less, more preferably 0.9 mass% or less, and even more preferably 0.8 mass% or less, from the viewpoint of preventing clogging of a particulate filter and the like.

[0208] In the lubricating oil composition according to the present embodiment, the sulfated ash content is 0.01 mass% or more.

[0209] The sulfated ash content can be measured in accordance with JIS K 2272:1998.

[Contents of Molybdenum Atom, Calcium Atom, Magnesium Atom, Boron Atom, and Phosphorus Atom]

[0210] The content of the molybdenum atom in the lubricating oil composition according to the present embodiment is preferably 0.01 mass% or more, more preferably 0.03 mass% or more, even more preferably 0.04 mass% or more, and still more preferably 0.05 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of improving the friction-reducing action. The content of the molybdenum atom is preferably 0.20 mass% or less, more preferably 0.15 mass% or less, even more preferably 0.12 mass% or less, and still more preferably 0.10 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of reducing the sulfated ash content.

[0211] The content of the calcium atom in the lubricating oil composition according to the present embodiment is preferably 0.05 mass% or more, more preferably 0.08 mass% or more, and even more preferably 0.10 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of high-temperature detergency and dispersibility. The content of the calcium atom is preferably 0.50 mass% or less, more preferably 0.40 mass% or less, even more preferably 0.30 mass% or less, still more preferably 0.20 mass% or less, even still more preferably 0.15 mass% or less, and yet still more preferably 0.14 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of reducing the sulfated ash content and the viewpoint of preventing LSPI (abnormal combustion).

[0212] The content of the magnesium atom in the lubricating oil composition according to the present embodiment is preferably 0.02 mass% or more, more preferably 0.03 mass% or more, and even more preferably 0.04 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of high-temperature detergency and dispersibility. The content of the magnesium atom is preferably 0.07 mass% or less, more preferably 0.06 mass% or less, and even more preferably 0.05 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of reducing a sulfated ash content and the viewpoint of preventing LSPI (abnormal combustion).

[0213] When the lubricating oil composition according to the present embodiment contains a boron atom, the content of the boron atom is generally 0.001 mass% or more based on the total amount (100 mass%) of the lubricating oil composition. From the viewpoint of high-temperature detergency, the content of the boron atom is preferably 0.10 mass% or less, more preferably 0.08 mass% or less, even more preferably 0.06 mass% or less, still more preferably 0.04 mass% or less, even still more preferably 0.03 mass% or less, and yet still more preferably 0.02 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0214] From the viewpoint of wear resistance, a content of a phosphorus atom in the lubricating oil composition according to the present embodiment is preferably 0.01 mass% or more, more preferably 0.03 mass% or more, and even more preferably 0.06 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition. The content of the phosphorus atom is preferably 0.12 mass% or less, more preferably 0.11 mass% or less, and even more preferably 0.10 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of preventing poisoning of an exhaust gas posttreatment device.

[0215] The contents of the molybdenum atom, the calcium atom, the magnesium atom, the boron atom, and the phosphorus atom can be measured in accordance with JPI-5S-38-03.

[Content of Nitrogen Atom]

[0216] The content of the nitrogen atom in the lubricating oil composition according to the present embodiment is preferably 0.03 mass% or more, and more preferably 0.04 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition, from the viewpoint of maintaining high-temperature detergency and dispersibility over a long period of time. From the viewpoint of low viscosity, the content of the nitrogen atom is preferably 0.20 mass% or less, more preferably 0.15 mass% or less, even more preferably 0.10 mass% or less, and still more preferably 0.09 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0217] The content of the nitrogen atom can be measured in accordance with JIS K 2609:1998.

[Friction Coefficient]

[0218] The friction coefficient of the lubricating oil composition according to the present embodiment can be evaluated using, for example, an SRV tester (manufactured by Optimol). Specifically, the evaluation can be performed by a method described in Examples described later. The friction coefficient in the method described in Examples described later is preferably 0.085 or less, and more preferably 0.080 or less.

[High-temperature Detergency and Dispersibility]

[0219] The high-temperature detergency and dispersibility of the lubricating oil composition according to the present embodiment can be evaluated, for example, by blowing NOx gas into a lubricating oil composition immediately after preparation to subject the lubricating oil composition to a deterioration treatment, and subjecting the deteriorated lubricating oil composition to a hot tube test. This evaluation result can also be said to reflect the maintainability of the high-temperature detergency and dispersibility of the lubricating oil composition.

[0220] Specifically, the evaluation can be performed by a method described in Examples described later. Among scores 0 to 10 of the hot tube test in the method described in Examples described later, a score of 7.0 or more is preferred, and a score of 8.0 or more is more preferred.

[Use of Lubricating Oil Composition]

[0221] The lubricating oil composition according to the present embodiment is excellent in effect of reducing a friction coefficient, and is also excellent in maintainability of the high-temperature detergency and dispersibility.

[0222] Therefore, the lubricating oil composition according to the present embodiment is preferably used in an internal combustion engine, and more preferably used in an internal combustion engine of a four-wheeled vehicle or a motorcycle.

[0223] The lubricating oil composition according to the present embodiment is preferably used as an engine oil, and more preferably used as a gasoline engine oil.

[0224] The lubricating oil composition according to the present embodiment is suitable for use as a lubricating oil composition for an internal combustion engine (an engine oil for an internal combustion engine) used in automobiles and the like, and can also be applied to other uses.

[Method for Producing Lubricating Oil Composition]

[0225] As the present embodiment, a method for producing a lubricating oil composition is provided including: a step of mixing a base oil (A), a molybdenum-based friction modifier (B), a metal-based detergent (C), and a dispersant (D), in which the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D 1), in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method, a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount (100 mass%) of the dispersant (D), and a kinematic viscosity at 100°C is 9.3 mm^2/s or less.

[0226] The method for mixing the above components is not particularly limited, and examples thereof include a step of adding the molybdenum-based friction modifier (B), the metal-based detergent (C), and the dispersant (D) to the base oil (A) and then mixing them.

[0227] The production method may further include a step of adding the other components described above.

[0228] Each component can be added in a form of a solution (dispersion) in which a diluent oil or the like is added. After each component is added, it is preferable to include a step of uniformly dispersing the components by stirring according to a known method.

[0229] According to an aspect of the present invention, the following [1] to [10] are provided.

[1] A lubricating oil composition containing:

a base oil (A);
a molybdenum-based friction modifier (B);
a metal-based detergent (C); and
a dispersant (D), in which
the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D 1),
a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method,
a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount (100 mass%) of the dispersant (D), and
a kinematic viscosity at 100°C is 9.3 mm^2/s or less.

[2] The lubricating oil composition according to the above [1], in which a content of a molybdenum atom derived from the molybdenum-based friction modifier (B) is 0.04 mass% or more and 0.10 mass% or less based on a total amount (100 mass%) of the lubricating oil composition.

[3] The lubricating oil composition according to the above [1] or [2], in which a ratio [(D 1)/(B)-Mo] of a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) to the content of the molybdenum atom derived from the molybdenum-based friction modifier (B) is 20 or more and 80 or less in mass ratio.

[4] The lubricating oil composition according to any one of the above [1] to [3], in which a sulfated ash content is 0.8 mass% or less.

[5] The lubricating oil composition according to any one of the above [1] to [4], in which when a metal atom contained

in the metal-based detergent (C) is calcium, a content of a calcium atom derived from the metal-based detergent (C) is 0.50 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

[6] The lubricating oil composition according to any one of the above [1] to [4], in which when the metal atom contained in the metal-based detergent (C) is magnesium, a content of a magnesium atom derived from the metal-based detergent (C) is 0.070 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

[7] The lubricating oil composition according to any one of the above [1] to [6], in which when the dispersant (D) contains a boron-modified succinimide (D3), a content of a boron atom derived from the boron-modified succinimide (D3) is 0.03 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

[8] The lubricating oil composition according to any one of the above [1] to [7], in which a content of a nitrogen atom derived from the total dispersant (D) is 0.10 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

[9] The lubricating oil composition according to any one of the above [1] to [8], which is used in an internal combustion engine.

[10] A method for producing a lubricating oil composition, including:

a step of mixing a base oil (A), a molybdenum-based friction modifier (B), a metal-based detergent (C), and a dispersant (D), in which
the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D1),
a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method,
a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount (100 mass%) of the dispersant (D), and
a kinematic viscosity at 100°C is 9.3 mm^2/s or less.

[Examples]

[0230] The present invention will be described in detail with reference to the following Examples, whereas the present invention is not limited to the following Examples. Various properties of components used in Examples and Comparative Examples and the obtained lubricating oil compositions were measured by the following methods.

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

[0231] A kinematic viscosity at 40°C, a kinematic viscosity at 100°C, and a viscosity index of the lubricating oil composition were measured or calculated in accordance with JIS K 2283:2000.

[HTHS Viscosity at 150°C]

[0232] An HTHS viscosity at 150°C was measured or calculated in accordance with JPI-5S-36-03.

[IR Spectrum]

[0233] An IR spectrum was determined by a liquid film method in accordance with JIS K0117. Using a KBr fixed cell having an optical path length of 0.1 mm, the evaluation was performed using a sample prepared by diluting the dispersant (D) in the base oil (A) such that a content of the dispersant (D) in the sample was 200 ppm in terms of a nitrogen atom.

- Apparatus name: FTIR-6200 (manufactured by JASCO Corporation)
- Resolution: 4 cm^{-1}
- Number of times of integration: 16 times
- Measurement temperature: room temperature

[Sulfated Ash Content]

[0234] A sulfated ash content in the lubricating oil composition was measured in accordance with JIS K 2272:1998.

[Base Number]

[0235] A base number was measured by a perchloric acid method in accordance with JIS K 2501:2003.

[Contents of Molybdenum Atom, Calcium Atom, Magnesium Atom, Boron Atom, and Phosphorus Atom]

[0236] Contents of a molybdenum atom, a calcium atom, a magnesium atom, a boron atom, and a phosphorus atom were measured in accordance with JPI-5S-38-03.

[Content of Nitrogen Atom]

[0237] A content of a nitrogen atom was measured in accordance with JIS K 2609:1998.

[Examples 1 to 15 and Comparative Examples 1 to 5]

[0238] Components shown below were added in contents shown in Tables 1 to 4 and sufficiently mixed to obtain lubricating oil compositions.
[0239] Details of the components used in Examples 1 to 15 and Comparative Examples 1 to 5 are as follows.
[0240] The contents in Tables 1 to 4 are contents in terms of a resin component.

<Base Oil (A)>

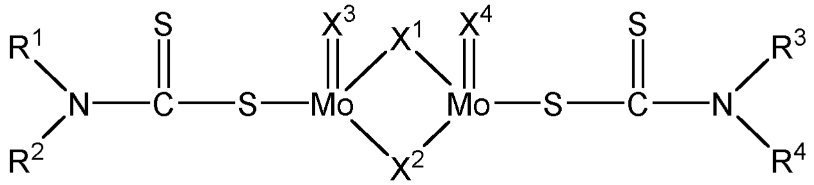
[0241]

- Mineral oil (classification in the API base oil categories: Group III, kinematic viscosity at 40°C: 19.8 mm^2/s, kinematic viscosity at 100°C: 4.0 mm^2/s, viscosity index: 125)

<Friction Modifier>

[0242]

- Molybdenum-based friction modifier (B): molybdenum dialkyldithiocarbamate represented by the following structural formula (B-3) (MoDTC, content of molybdenum atom: 10.0 mass%)



(B-3)

[In the structural formula (B-3), R^1, R2, R^3, and R^4 are each independently selected from an isooctyl group (number of carbon atoms: 8, short-chain substituent group) and an isotridecyl group (number of carbon atoms: 13, long-chain substituent group), and a molar ratio of the isooctyl group to the isotridecyl group in all molecules of molybdenum dialkyldithiocarbamate is 50:50. X^1 and X^2 are sulfur atoms, and X^3 and X^4 are oxygen atoms.]
- Diethanolamine: oleyl diethanolamine

<Metal-based Detergent (C)>

[0243]

- Calcium-based detergent (C1-1): calcium salicylate (base number: 230 mgKOH/g, content of calcium atom: 8 mass%)
- Calcium-based detergent (C1-2): calcium sulfonate (base number: 300 mgKOH/g, content of calcium atom: 12 mass%)
- Magnesium-based detergent (C2-1): magnesium sulfonate (base number: 400 mgKOH/g, content of magnesium atom: 9.5 mass%)
- Magnesium-based detergent (C2-2): magnesium sulfonate (base number: 400 mgKOH/g, content of magnesium atom: 9.7 mass%)

<Dispersant (D)>

[0244]

- Non-boron-modified polyisobutenyl succinic bisimide (D1-1): (mass average molecular weight (Mw) of polyisobutenyl group: 2,300, content of nitrogen atom: 1.4 mass%, [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})]: 6.0)
- Non-boron-modified polyisobutenyl succinic bisimide (D1-2): (mass average molecular weight (Mw) of polyisobutenyl group: 2,300, content of nitrogen atom: 1.2 mass%, [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})]: 7.1)
- Non-boron-modified succinimide (D2): non-boron-modified polyisobutenyl succinic bisimide (mass average molecular weight (Mw) of polyisobutenyl group: 2,300, content of nitrogen atom: 1.0 mass%, [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})]: 7.9)
- Boron-modified succinimide (D3-1): (polybutene skeleton, mass average molecular weight (Mw) of polyisobutenyl group: 2,300, content of nitrogen atom: 1.4 mass%, content of boron atom: 2.5 mass%, [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})]: 6.9)
- Boron-modified succinimide (D3-2): (polybutene skeleton, mass average molecular weight (Mw) of polyisobutenyl group: 2,300, content of nitrogen atom: 1.4 mass%, content of boron atom: 1.3 mass%, [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})]: 7.3)

<Viscosity Index Improver>

[0245]

- Polymethacrylate (mass average molecular weight (Mw): 400,000, (Mw/Mn): 1.7, permanent shear stability index (PSSI): 30)
- Star polymer (mass average molecular weight (Mw): 610,000, (Mw/Mn): 1.1, permanent shear stability index (PSSI): 12)

<Other Components>

[0246] Pour point depressant, antioxidant, and zinc dialkyldithiophosphate (ZnDTP)

[Content of Atom]

[0247] In Tables 1 to 4, the content of the molybdenum atom in the lubricating oil composition is a value reflecting the content of the molybdenum atom derived from the molybdenum-based friction modifier (B).

[0248] In Tables 1 to 4, the contents of the calcium atom and the magnesium atom in the lubricating oil composition are values reflecting the contents of the calcium atom and the magnesium atom derived from the metal-based detergent (C).

[0249] In Tables 1 to 4, the content of the boron atom in the lubricating oil composition is a value reflecting the content of the boron atom derived from the boron-modified succinimide (D3).

[0250] In Tables 1 to 4, the content of the phosphorus atom in the lubricating oil composition is a value reflecting the content of the phosphorus atom derived from ZnDTP which is another additive.

[0251] In Tables 1 to 4, the content of the nitrogen atom in the lubricating oil composition is a value reflecting the content of the nitrogen atom derived from the non-boron-modified polyisobutenyl succinic bisimide (D1), the non-boron-modified succinimide (D2), and the boron-modified succinimide (D3).

[Ratio]

[0252] The "content ratio of the non-boron-modified polyisobutenyl succinic bisimide (D1) based on the total amount (100 mass%) of the dispersant (D)" was calculated by dividing the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) having a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of 7.5 or less, that is, the content of the non-boron-modified polyisobutenyl succinic bisimide (D1-1) or (D1-2) by the total content of the dispersant (D).

[0253] The "ratio of the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) to the content of the molybdenum atom derived from the molybdenum-based friction modifier (B)" was calculated by dividing the content of the non-boron-modified polyisobutenyl succinic bisimide (D1) having a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of 7.5 or less, that is, the content of the non-boron-modified polyisobutenyl succinic bisimide (D1-1) or (D1-2) by the content of the molybdenum atom derived from the molybdenum-based friction modifier (B).

[0254] The obtained lubricating oil compositions were evaluated as follows. The results are shown in Tables 1 to 4.

[Evaluation of Effect of Reducing Friction Coefficient]

[0255] The friction coefficient when the prepared lubricating oil composition was used was measured using an SRV tester (manufactured by Optimol) under the following conditions.

[0256] First, while the temperature was increased from 30°C to 140°C in a rate of 10°C, the test was performed for 5 minutes at each temperature while sliding under the following conditions.

[0257] The friction coefficient was measured every 1 second in the final 1 minute in the test at 140°C, and the average value of the friction coefficient in the final 1 minute was calculated.

[0258] The rate of change from the friction coefficient in Comparative Example 3 was calculated by dividing a "difference between the friction coefficient of each lubricating oil composition and the friction coefficient of the lubricating oil composition in Comparative Example 3" by the "friction coefficient of the lubricating oil composition in Comparative Example 3".

- Cylinder: AISI 52100
- Disk: AISI 52100
- Frequency: 50 Hz
- Amplitude: 1.5 mm
- Load: 400 N
- Temperature: 30°C to 140°C, temperature increase rate: 10°C
- Test time: 5 minutes at each temperature

[Evaluation of Maintainability of High-temperature Detergency and Dispersibility]

[0259] A hot tube test in accordance with JPI-5S-55-99 was performed at a temperature of 280°C. Among scores of 0 to 10 in the hot tube test, when the score was 7.0 or more, the lubricating oil composition was evaluated as a lubricating oil composition in which high-temperature detergency and dispersibility was maintained for a long period of time.

Table 1

			Example				
			1	2	3	4	5
Base oil (A)		mass%	89.55	91.55	89.85	91.55	91.85
Friction modifier	Molybdenum-based friction modifier (B)	mass%	0.70	0.70	0.70	0.70	0.70
	Diethanolamine	mass%	0.30	0.30	-	-	-
Metal-based detergent (C)	Calcium-based detergent (C1-1)	mass%	1.60	1.60	1.60	1.60	1.60
	Calcium-based detergent (C1-2)	mass%	-	-	-	-	-
	Magnesium-based detergent (C2-1)	mass%	0.40	0.40	0.40	0.40	0.40
	Magnesium-based detergent (C2-2)	mass%	-	-	-	-	-

(continued)

			Example				
			1	2	3	4	5
Dispersant (D)	Non-boron-modified polyisobutenyl succinic bisimide (D1-1)	mass%	-	-	-	-	-
	Non-boron-modified polyisobutenyl succinic bisimide (D1-2)	mass%	2.50	2.50	2.50	2.50	2.50
	Non-boron-modified succinimide (D2)	mass%	-	-	-	-	-
	Boron-modified succinimide (D3-1)	mass%	-	-	-	0.30	-
	Boron-modified succinimide (D3-2)	mass%	2.00	-	2.00	-	-
Viscosity index improver (E)	Polymethacrylate	mass%	-	-	-	-	-
	Star polymer	mass%	-	-	-	-	-
Other components		mass%	2.95	2.95	2.95	2.95	2.95
Total		mass%	100.00	100.00	100.00	100.00	100.00
Total metal-based detergent (C)		mass%	2.00	2.00	2.00	2.00	2.00
Total dispersant (D)		mass%	4.50	2.50	4.50	2.80	2.50
[(D1)/ Total (D)]		-	56	100	56	89	100
[(DI)/(D2)]		-	-	-	-	-	-
[(D1)/(D3)]		-	1.3	-	1.3	8.3	-
[(D1)/(B)-Mo]		-	42	42	42	42	42
[(N derived from (D1)/B derived from (D3)]		-	1.5	-	1.0	3.0	-
Physical properties	Kinematic viscosity at 40°C	mm2/s	26.4	24.8	26.7	25.2	25.0
	Kinematic viscosity at 100°C	mm2/s	5.3	5.1	5.4	5.1	5.1
	HTHS viscosity at 150°C	mPa•s	1.9	1.8	1.9	1.8	1.8
	Viscosity index	-	138	139	142	135	137
	Sulfated ash content	mass%	0.8	0.8	0.8	0.8	0.8

(continued)

			Example				
			1	2	3	4	5
Content of atom in lubricating oil composition	Molybdenum	mass%	0.06	0.06	0.06	0.06	0.06
	Calcium	mass%	0.13	0.13	0.13	0.13	0.13
	Magnesium	mass%	0.04	0.04	0.04	0.04	0.04
	Boron	mass%	0.02	-	0.03	0.01	-
	Phosphorus	mass%	0.08	0.08	0.08	0.08	0.08
	Nitrogen in total amount of lubricating oil composition	mass%	0.12	0.10	0.10	0.08	0.08
	Nitrogen derived from (D1)	mass%	0.03	0.03	0.03	0.03	0.03
	Nitrogen derived from (D2)	mass%	-	-	-	-	-
	Nitrogen derived from (D3)	mass%	0.03	-	0.03	0.004	-
	Nitrogen derived from total dispersant (D)	mass%	0.06	0.03	0.06	0.03	0.03
Evaluation result	Friction coefficient	-	0.082	0.082	0.075	0.077	0.064
	Rate of change from friction coefficient in Comparative Example 3	%	-13	-12	-20	-18	-32
	Hot tube test (maintainability of high-temperature detergency and dispersibility)	Score	8.5	8.0	8.5	-	8.0

Table 2

			Example				
			6	7	8	9	10
Base oil (A)		mass%	90.55	90.85	91.15	91.85	91.85
Friction modifier	Molybdenum-based friction modifier (B)	mass%	0.70	0.70	0.40	0.70	0.70
	Diethanolamine	mass%	-	-	-	-	-
Metal-based detergent (C)	Calcium-based detergent (C1-1)	mass%	1.60	1.60	1.60	1.60	1.60
	Calcium-based detergent (C1-2)	mass%	-	-	-	-	-
	Magnesium-based detergent (C2-1)	mass%	0.40	0.40	0.40	0.40	0.40
	Magnesium-based detergent (C2-2)	mass%	-	-	-	-	-

(continued)

			Example				
			6	7	8	9	10
Dispersant (D)	Non-boron-modified polyisobutenyl succinic bisimide (D1-1)	mass%	-	-	-	-	-
	Non-boron-modified polyisobutenyl succinic bisimide (D1-2)	mass%	3.50	3.50	3.50	1.25	1.67
	Non-boron-modified succinimide (D2)	mass%	-	-	-	1.25	0.83
	Boron-modified succinimide (D3-1)	mass%	0.30	-	-	-	-
	Boron-modified succinimide (D3-2)	mass%	-	-	-	-	-
Viscosity index improver (E)	Polymethacrylate	mass%	-	-	-	-	-
	Star polymer	mass%	-	-	-	-	-
Other components		mass%	2.95	2.95	2.95	2.95	2.95
Total		mass%	100.00	100.00	100.00	100.00	100.00
Total metal-based detergent (C)		mass%	2.00	2.00	2.00	2.00	2.00
Total dispersant (D)		mass%	3.80	3.50	3.50	2.50	2.50
[(D1)/ Total (D)]		-	92	100	100	50	67
[(DI)/(D2)]		-	-	-	-	1.0	2.0
[(D1)/(D3)]		-	11.7	-	-	-	-
[(D1)/(B)-Mo]		-	58	58	88	21	28
[(N derived from (D1)/B derived from (D3)]		-	4.2	-	-	-	-
Physical properties	Kinematic viscosity at 40°C	mm2/s	26.9	26.7	26.7	24.6	24.8
	Kinematic viscosity at 100°C	mm2/s	5.4	5.4	5.4	5.1	5.1
	HTHS viscosity at 150°C	mPa•s	1.9	1.9	1.9	1.8	1.8
	Viscosity index	-	140	142	142	141	139
	Sulfated ash content	mass%	0.8	0.8	0.8	0.8	0.8

(continued)

			Example				
			6	7	8	9	10
Content of atom in lubricating oil composition	Molybdenum	mass%	0.06	0.06	0.04	0.06	0.06
	Calcium	mass%	0.13	0.13	0.13	0.13	0.13
	Magnesium	mass%	0.04	0.04	0.04	0.04	0.04
	Boron	mass%	0.01	-	-	-	-
	Phosphorus	mass%	0.08	0.08	0.08	0.08	0.08
	Nitrogen in total amount of lubricating oil composition	mass%	0.09	0.09	0.09	0.08	0.08
	Nitrogen derived from (D1)	mass%	0.04	0.04	0.04	0.02	0.02
	Nitrogen derived from (D2)	mass%	-	-	-	0.01	0.01
	Nitrogen derived from (D3)	mass%	0.004	-	-	-	-
	Nitrogen derived from total dispersant (D)	mass%	0.05	0.04	0.04	0.03	0.03
Evaluation result	Friction coefficient	-	0.069	0.066	0.085	0.070	0.069
	Rate of change from friction coefficient in Comparative Example 3	%	-26	-30	-9	-25	-26
	Hot tube test (maintainability of high-temperature detergency and dispersibility)	Score	-	-	-	8.0	8.0

Table 3

			Example				
			11	12	13	14	15
Base oil (A)		mass%	91.05	91.75	91.45	90.70	90.14
Friction modifier	Molybdenum-based friction modifier (B)	mass%	0.70	0.70	1.00	0.70	0.70
	Diethanolamine	mass%	-	-	-	-	-
Metal-based detergent (C)	Calcium-based detergent (C1-1)	mass%	-	-	-	-	-
	Calcium-based detergent (C1-2)	mass%	1.00	1.00	1.00	1.00	1.00
	Magnesium-based detergent (C2-1)	mass%	-	-	-	-	-
	Magnesium-based detergent (C2-2)	mass%	0.50	0.50	0.50	0.50	0.50

(continued)

			Example				
			11	12	13	14	15
Dispersant (D)	Non-boron-modified polyisobutenyl succinic bisimide (D1-1)	mass%	-	2.80	2.80	2.80	2.80
	Non-boron-modified polyisobutenyl succinic bisimide (D1-2)	mass%	3.50	-	-	-	-
	Non-boron-modified succinimide (D2)	mass%	-	-	-	-	-
	Boron-modified succinimide (D3-1)	mass%	0.30	0.30	0.30	0.30	0.30
	Boron-modified succinimide (D3-2)	mass%	-	-	-	-	-
Viscosity index improver (E)	Polymethacrylate	mass%	-	-	-	1.05	1.53
	Star polymer	mass%	-	-	-	-	0.08
Other components		mass%	2.95	2.95	2.95	2.95	2.95
Total		mass%	100.00	100.00	100.00	100.00	100.00
Total metal-based detergent (C)		mass%	1.50	1.50	1.50	1.50	1.50
Total dispersant (D)		mass%	3.80	3.10	3.10	3.10	3.10
[(D1)/ Total (D)]		-	92	90	90	90	90
[(DI)/(D2)]		-	-	-	-	-	-
[(D1)/(D3)]		-	11.7	9.3	9.3	9.3	9.3
[(D1)/(B)-Mo]		-	58	47	28	47	47
[(N derived from (D1)/B derived from (D3)]		-	4.2	3.9	3.9	3.9	3.9
Physical properties	Kinematic viscosity at 40°C	mm2/s	25.9	25.2	25.2	30.7	36.6
	Kinematic viscosity at 100°C	mm2/s	5.3	5.2	5.2	7.0	8.6
	HTHS viscosity at 150°C	mPa•s	1.8	1.8	1.8	2.3	2.6
	Viscosity index	-	143	142	142	203	226
	Sulfated ash content	mass%	0.8	0.8	0.8	0.8	0.8

(continued)

			Example				
			11	12	13	14	15
Content of atom in lubricating oil composition	Molybdenum	mass%	0.06	0.06	0.10	0.06	0.06
	Calcium	mass%	0.11	0.11	0.11	0.11	0.11
	Magnesium	mass%	0.05	0.05	0.05	0.05	0.05
	Boron	mass%	0.01	0.01	0.01	0.01	0.01
	Phosphorus	mass%	0.08	0.08	0.08	0.08	0.08
	Nitrogen in total amount of lubricating oil composition	mass%	0.09	0.09	0.09	0.09	0.09
	Nitrogen derived from (D1)	mass%	0.04	0.04	0.04	0.04	0.04
	Nitrogen derived from (D2)	mass%	-	-	-	-	-
	Nitrogen derived from (D3)	mass%	0.004	0.004	0.004	0.004	0.004
	Nitrogen derived from total dispersant (D)	mass%	0.05	0.04	0.04	0.04	0.04
Evaluation result	Friction coefficient	-	0.071	0.077	0.063	0.074	0.073
	Rate of change from friction coefficient in Comparative Example 3	%	-24	-18	-33	-21	-22
	Hot tube test (maintainability of high-temperature detergency and dispersibility)	Score	7.0	7.0	-	7.0	7.0

Table 4

			Comparative Example				
			1	2	3	4	5
Base oil (A)		mass%	91.05	91.05	89.55	91.55	91.85
Friction modifier	Molybdenum-based friction modifier (B)	mass%	0.70	0.70	0.70	0.70	0.70
	Diethanolamine	mass%	0.30	0.30	0.30	0.30	-
Metal-based detergent (C)	Calcium-based detergent (C1-1)	mass%	1.60	1.60	1.60	1.60	1.60
	Calcium-based detergent (C1-2)	mass%	-	-	-	-	-
	Magnesium-based detergent (C2-1)	mass%	0.40	0.40	0.40	0.40	0.40
	Magnesium-based detergent (C2-2)	mass%	-	-	-	-	-

(continued)

			Comparative Example				
			1	2	3	4	5
Dispersant (D)	Non-boron-modified polyisobutenyl succinic bisimide (D1-1)	mass%	-	-	-	-	-
	Non-boron-modified polyisobutenyl succinic bisimide (D1-2)	mass%	1.00	-	-	-	-
	Non-boron-modified succinimide (D2)	mass%	-	1.00	2.50	2.50	2.50
	Boron-modified succinimide (D3-1)	mass%	-	-	-	-	-
	Boron-modified succinimide (D3-2)	mass%	2.00	2.00	2.00	-	-
Viscosity index improver (E)	Polymethacrylate	mass%	-	-	-	-	-
	Star polymer	mass%	-	-	-	-	-
Other components		mass%	2.95	2.95	2.95	2.95	2.95
Total		mass%	100.00	100.00	100.00	100.00	100.00
Total metal-based detergent (C)		mass%	2.00	2.00	2.00	2.00	2.00
Total dispersant (D)		mass%	3.00	3.00	4.50	2.50	2.50
[(D1)/ Total (D)]		-	33	-	-	-	-
[(D1)/(D2)]		-	-	-	-	-	-
[(D1)/(D3)]		-	0.5	-	-	-	-
[(D1)/(B)-Mo]		-	17	-	-	-	-
[(N derived from (D1)/ B derived from (D3)]		-	0.6	-	-	-	-
Physical properties	Kinematic viscosity at 40°C	mm2/s	24.0	23.6	25.4	23.9	24.1
	Kinematic viscosity at 100°C	mm2/s	4.9	4.9	5.2	4.9	5.0
	HTHS viscosity at 150°C	mPa•s	1.7	1.7	1.8	1.7	1.8
	Viscosity index	-	131	135	140	132	138
	Sulfated ash content	mass%	0.8	0.8	0.8	0.8	0.8

(continued)

			Comparative Example				
			1	2	3	4	5
Content of atom in lubricating oil composition	Molybdenum	mass%	0.06	0.06	0.06	0.06	0.06
	Calcium	mass%	0.13	0.13	0.13	0.13	0.13
	Magnesium	mass%	0.04	0.04	0.04	0.04	0.04
	Boron	mass%	0.02	0.03	0.03	-	-
	Phosphorus	mass%	0.08	0.08	0.08	0.08	0.08
	Nitrogen in total amount of lubricating oil composition	mass%	0.10	0.10	0.11	0.09	0.08
	Nitrogen derived from (D1)	mass%	0.01	-	-	-	-
	Nitrogen derived from (D2)	mass%	-	0.01	0.03	0.03	0.03
	Nitrogen derived from (D3)	mass%	0.03	0.03	0.03	-	-
	Nitrogen derived from total dispersant (D)	mass%	0.04	0.04	0.05	0.03	0.03
Evaluation result	Friction coefficient	-	0.097	0.106	0.094	0.090	0.091
	Rate of change from friction coefficient in Comparative Example 3	%	3	13	0	-4	-3
	Hot tube test (maintainability of high-temperature detergency and dispersibility)	Score	7.0	7.0	8.5	8.0	8.0

[0260] As can be seen from Tables 1 to 3, the lubricating oil compositions in Examples 1 to 15 that satisfy all of the compositions of the present invention have a low friction coefficient and a higher rate of decrease in friction coefficient than the friction coefficient in Comparative Example 3, indicating that the effect of reducing a friction coefficient is excellent.

[0261] On the other hand, as can be seen from Table 4, the lubricating oil compositions in Comparative Examples 1 to 5 have a higher friction coefficient than that of the lubricating oil compositions in Examples 1 to 15, and do not exhibit the effect of reducing a friction coefficient.

Claims

1. A lubricating oil composition comprising:

a base oil (A);
a molybdenum-based friction modifier (B);
a metal-based detergent (C); and
a dispersant (D), wherein
the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D1),
a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 $cm^{-1)}$ at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method,
a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount (100 mass%) of the dispersant (D), and
a kinematic viscosity at 100°C is 9.3 mm^2/s or less.

2. The lubricating oil composition according to claim 1, wherein a content of a molybdenum atom derived from the molybdenum-based friction modifier (B) is 0.04 mass% or more and 0.10 mass% or less based on a total amount

(100 mass%) of the lubricating oil composition.

3. The lubricating oil composition according to claim 1 or 2, wherein a ratio [(D1)/(B)-Mo] of a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) to the content of the molybdenum atom derived from the molybdenum-based friction modifier (B) is 20 or more and 80 or less in mass ratio.

4. The lubricating oil composition according to any one of claims 1 to 3, wherein a sulfated ash content is 0.8 mass% or less.

5. The lubricating oil composition according to any one of claims 1 to 4, wherein when a metal atom contained in the metal-based detergent (C) is calcium, a content of a calcium atom derived from the metal-based detergent (C) is 0.50 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

6. The lubricating oil composition according to any one of claims 1 to 4, wherein when the metal atom contained in the metal-based detergent (C) is magnesium, a content of a magnesium atom derived from the metal-based detergent (C) is 0.070 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

7. The lubricating oil composition according to any one of claims 1 to 6, wherein when the dispersant (D) contains a boron-modified succinimide (D3), a content of a boron atom derived from the boron-modified succinimide (D3) is 0.03 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

8. The lubricating oil composition according to any one of claims 1 to 7, wherein a content of a nitrogen atom derived from the total dispersant (D) is 0.10 mass% or less based on the total amount (100 mass%) of the lubricating oil composition.

9. The lubricating oil composition according to any one of claims 1 to 8, which is used in an internal combustion engine.

10. A method for producing a lubricating oil composition, comprising:

a step of mixing a base oil (A), a molybdenum-based friction modifier (B), a metal-based detergent (C), and a dispersant (D), wherein
the dispersant (D) contains a non-boron-modified polyisobutenyl succinic bisimide (D1),
a ratio [Abs (1705 cm^{-1})/Abs (1390 cm^{-1})] of a peak intensity Abs (1705 cm^{-1}) at 1705 cm^{-1} to a peak intensity Abs (1390 cm^{-1}) at 1390 cm^{-1} is 7.5 or less, in an IR spectrum of the non-boron-modified polyisobutenyl succinic bisimide (D1) as determined by an FT-IR method,
a content of the non-boron-modified polyisobutenyl succinic bisimide (D1) is 50 mass% or more based on a total amount (100 mass%) of the dispersant (D), and
a kinematic viscosity at 100°C is 9.3 mm^2/s or less.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/004403

A. CLASSIFICATION OF SUBJECT MATTER

C10M 141/08(2006.01)i; *C10N 10/04*(2006.01)n; *C10N 10/12*(2006.01)n; *C10N 30/06*(2006.01)n; *C10N 30/08*(2006.01)n; *C10N 40/25*(2006.01)n; ***C10M 133/56***(2006.01)i; ***C10M 139/00***(2006.01)i
FI: C10M141/08; C10M133/56; C10M139/00 Z; C10N10:12; C10N10:04; C10N30:06; C10N40:25; C10N30:08

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)

C10M141/08; C10N10/04; C10N10/12; C10N30/06; C10N30/08; C10N40/25; C10M133/56; C10M139/00

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.
A	JP 10-183153 A (IDEMITSU KOSAN CO LTD) 14 July 1998 (1998-07-14) claims, table 1, paragraph [0038]	1-10
A	JP 2019-178319 A (IDEMITSU KOSAN CO LTD) 17 October 2019 (2019-10-17) claims, paragraphs [0026]-[0029]	1-10
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A	JP 2020-186383 A (INFINIUM INTERNATIONAL LIMITED) 19 November 2020 (2020-11-19) claims 1, 12-13, paragraph [0036]	1-10

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

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Date of the actual completion of the international search	Date of mailing of the international search report
08 April 2022	**19 April 2022**

Name and mailing address of the ISA/JP	Authorized officer
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INTERNATIONAL SEARCH REPORT
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International application No.
PCT/JP2022/004403

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