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

(11) **EP 4 368 688 A1**

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

(43) Date of publication:
15.05.2024 Bulletin 2024/20

(21) Application number: **22837550.7**

(22) Date of filing: **29.06.2022**

(51) International Patent Classification (IPC):
C10M 141/08 *(2006.01)* ***C10N 30/00*** *(2006.01)*
C10N 30/06 *(2006.01)* ***C10N 30/10*** *(2006.01)*
C10N 30/14 *(2006.01)* ***C10N 40/04*** *(2006.01)*
C10N 40/08 *(2006.01)* ***C10N 40/25*** *(2006.01)*
C10N 40/30 *(2006.01)* ***C10M 133/16*** *(2006.01)*
C10M 133/56 *(2006.01)* ***C10M 135/36*** *(2006.01)*
C10M 137/02 *(2006.01)* ***C10M 137/04*** *(2006.01)*
C10M 137/10 *(2006.01)* ***C10M 139/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C10M 141/08; C10M 133/16; C10M 133/56; C10M 135/36; C10M 137/02; C10M 137/04; C10M 137/10; C10M 139/00; C10N 2030/00; C10N 2030/06; C10N 2030/10; C10N 2030/14; C10N 2040/04; C10N 2040/08; C10N 2040/25;

(Cont.)

(86) International application number:
PCT/JP2022/025869

(87) International publication number:
WO 2023/282134 (12.01.2023 Gazette 2023/02)

(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: **05.07.2021 JP 2021111291**

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(54) **LUBRICANT COMPOSITION**

(57) Provided is a lubricating oil composition containing a base oil (A), a thiadiazole-based compound (B) and a boron-modified alkenyl succinimide (C), wherein a content of the component (B) is less than 0.60 mass% based on the total amount of the lubricating oil composition, a content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) is 0.35 or more, and a content of boron atoms derived from the component (C) is 300 ppm by mass or less based on the total amount of the lubricating oil composition.

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(52) Cooperative Patent Classification (CPC): (Cont.)
C10N 2040/30

Description

Technical Field

[0001] The present invention relates to a lubricating oil composition, a speed reducer, and use of a lubricating oil composition.

Background Art

[0002] Various apparatuses such as an engine, a transmission, a speed reducer, a compressor and a hydraulic system have mechanisms such as a torque converter, a wet clutch, a gear bearing mechanism, an oil pump and a hydraulic control mechanism. In these mechanisms, lubricating oil compositions are used, and lubricating oil compositions capable of meeting various requirements have been developed.

[0003] For example, Patent Literature 1 discloses a gear oil composition comprising: a base oil comprising a blend of a low-viscosity mineral oil-based lubricating base oil and a high-viscosity solvent-refined mineral oil-based lubricating oil in a predetermined ratio; and a zinc dialkyldithiophosphate and an alkaline earth metal-based detergent in predetermined amounts, for the purpose of providing a gear oil composition having a fuel saving performance and providing gears, bearings, etc. with sufficient durability.

Citation List

Patent Literature

[0004] Patent Literature 1: JP-A-2012-193255

Summary of Invention

Technical Problem

[0005] By the way, for example, a lubricating oil composition used for various apparatuses such as an electric motor sometimes requires not only insulation properties but also, depending on the mode of the apparatus, characteristics of scuffing resistance, copper elution suppressing effect, oxidation stability, etc. That is to say, a novel lubricating oil composition having characteristics (e.g., scuffing resistance, copper elution suppressing effect, oxidation stability, insulation properties) suitable for lubrication meeting various mechanisms incorporated in apparatuses has been desired.

Solution to Problem

[0006] The present invention provides a lubricating oil composition comprising a thiadiazole-based compound and a boron-modified alkenyl succinimide, together with a base oil, wherein a content of the thiadiazole-based compound and contents of boron atoms and nitrogen atoms derived from the boron-modified alkenyl succinimide have been adjusted to be in predetermined ranges.

[0007] Specifically, the present invention provides lubricating oil compositions according to the following embodiments [1] to [14], a speed reducer and use of a lubricating oil composition.

[1] A lubricating oil composition comprising a base oil (A), a thiadiazole-based compound (B) and a boron-modified alkenyl succinimide (C), wherein

a content of the component (B) is less than 0.60 mass% based on the total amount of the lubricating oil composition,
a content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) is 0.35 or more, and
a content of boron atoms derived from the component (C) is 300 ppm by mass or less based on the total amount of the lubricating oil composition.

[2] The lubricating oil composition according to the above [1], wherein a content of nitrogen atoms derived from the component (C) is 320 ppm by mass or less based on the total amount of the lubricating oil composition.

[3] The lubricating oil composition according to the above [1] or [2], wherein a content of nitrogen atoms derived from the component (C) is 5.0 to 320 ppm by mass based on the total amount of the lubricating oil composition.

[4] The lubricating oil composition according to any one of the above [1] to [3], wherein the content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) is 0.35 to 2.0.
[5] The lubricating oil composition according to any one of the above [1] to [4], wherein the content of boron atoms derived from the component (C) is 3.0 to 300 ppm by mass based on the total amount of the lubricating oil composition.
[6] The lubricating oil composition according to any one of the above [1] to [5], wherein the component (C) comprises a boron-modified alkenyl bis-succinimide (C1).
[7] The lubricating oil composition according to any one of the above [1] to [6], wherein the component (B) comprises a thiadiazole-based compound (B1) having a branched chain alkyl group.
[8] The lubricating oil composition according to any one of the above [1] to [7], wherein a content of a sulfurized olefin is less than 0.20 mass% based on the total amount of the lubricating oil composition.
[9] The lubricating oil composition according to any one of the above [1] to [8], wherein a kinematic viscosity of the lubricating oil composition at 100°C is 2.1 mm^2/s or more and less than 5.0 mm^2/s.
[10] The lubricating oil composition according to any one of the above [1] to [9], further comprising one or more phosphorus-based compounds (D) selected from a phosphoric acid ester and a phosphorous acid ester.
[11] The lubricating oil composition according to the above [10], wherein the component (D) comprises one or more sulfur-phosphorus-based compounds (D1) selected from a sulfur atom-containing phosphoric acid ester and a sulfur atom-containing phosphorous acid ester.
[12] The lubricating oil composition according to any one of the above [1] to [11], being used for lubrication of a speed reducer.
[13] A speed reducer to which the lubricating oil composition according to any one of the above [1] to [12] has been applied.
[14] Use of a lubricating oil composition, wherein the lubricating oil composition according to any one of the above [1] to [12] is applied to lubrication of a speed reducer.

Advantageous Effects of Invention

[0008] The lubricating oil composition of one preferred embodiment of the present invention is a lubricating oil composition having characteristics suitable for various mechanisms incorporated in apparatuses, and the lubricating oil composition of a more preferred embodiment of the present invention can be improved in characteristics of scuffing resistance, copper elution suppressing effect, oxidation stability, insulation properties, etc. in a balanced manner. On that account, these lubricating oil compositions can be preferably used for lubrication of a speed reducer, etc.

Description of Embodiments

[0009] Regarding the numerical range described in the present specification, the upper limit and the lower limit can be arbitrarily combined. For example, with the description "preferably 30 to 100, more preferably 40 to 80" as a numerical range, the range of "30 to 80" and the range of "40 to 100" are also included in the numerical range described in the present specification. Alternatively, for example, with the description "preferably 30 or more, more preferably 40 or more, and preferably 100 or less, more preferably 80 or less" as a numerical range, the range of "30 to 80" and the range of "40 to 100" are also included in the numerical range described in the present specification.
[0010] In addition, for example, the description of "60 to 100" as the numerical range described in the present specification means a range of "60 or more and 100 or less".
[0011] In the present specification, the kinematic viscosity and the viscosity index mean values measured or calculated in accordance with JIS K2283:2000.
[0012] In the present specification, the contents of boron atoms and phosphorus atoms mean values measured in accordance with JPI-5S-38-92.
[0013] In the present specification, the content of nitrogen atoms means a value measured in accordance with JIS K2609.
[0014] In the present specification, the content of sulfur atoms means a value measured in accordance with JIS K2541-6:2013.

[Constitution of lubricating oil composition]

[0015] The lubricating oil composition of one embodiment of the present invention comprises a base oil (A) (also referred to as a "component (A)" hereinafter), a thiadiazole-based compound (also referred to as a "component (B)" hereinafter), and a boron-modified alkenyl succinimide (also referred to as a "component (C)" hereinafter).
[0016] In lubrication on a sliding contact surface, such as a tooth surface in various mechanisms incorporated in apparatuses, occurrence of localized surface damage called scuffing, which is due to solid phase adhesion, becomes

a problem. According to the study by the present inventors, it has been found that the lower the kinematic viscosity of a lubricating oil composition is, the more the scuffing is liable to occur. Moreover, in the lubricating oil composition having a low kinematic viscosity, reduction of volume resistivity is also observed, and a problem of insulation properties also occurs.

[0017] The present inventors have found that by preparing a lubricating oil composition containing a thiadiazole-based compound, scuffing resistance is improved, but they have also found that novel problems of increase in elution amount of copper and decrease in oxidation stability occur at the same time. Therefore, the present inventors have made various studies in order to solve such problems, and as a result, they have acquired knowledge that by preparing a lubricating oil composition containing not only a thiadiazole-based compound but also a boron-modified alkenyl succinimide and by adjusting a content of the thiadiazole-based compound in the lubricating oil composition and contents of boron atoms and nitrogen atoms derived from the boron-modified alkenyl succinimide to be in predetermined ranges, the lubricating oil composition can become a lubricating oil composition having been improved in characteristics of scuffing resistance, copper elution suppressing effect, oxidation stability, insulation properties, etc. in a balanced manner. The lubricating oil composition of one embodiment of the present invention has been made based on this knowledge.

[0018] The lubricating oil composition of one embodiment of the present invention preferably further contains one or more phosphorus-based compounds (D) (also referred to as a "component (D)" hereinafter) selected from a phosphoric acid ester and a phosphorous acid ester, from the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance.

[0019] The lubricating oil composition of one embodiment of the present invention may further contain various additives other than the components (B) to (D) when needed as long as the effects of the present invention are not impaired.

[0020] In the lubricating oil composition of one embodiment of the present invention, the total content of the components (A), (B) and (C) is preferably 50 mass% or more, more preferably 60 mass% or more, still more preferably 70 mass% or more, still much more preferably 75 mass% or more, and particularly preferably 80 mass% or more, or may be 85 mass% or more, 90 mass% or more, or 92 mass% or more, and it may be 100 mass% or less, 99.5 mass% or less, 99.0 mass% or less, 98.5 mass% or less, 98.0 mass% or less, 97.5 mass% or less, 97.0 mass% or less, 96.5 mass% or less, or 96.0 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0021] In the lubricating oil composition of one embodiment of the present invention, the total content of the components (A), (B), (C) and (D) is preferably more than 50 mass%, more preferably more than 60 mass%, still more preferably more than 70 mass%, still much more preferably more than 75 mass%, and particularly preferably more than 80 mass%, or may be more than 83 mass%, more than 85 mass%, more than 87 mass%, more than 90 mass%, more than 92 mass%, or 94 mass% or more, and it may be 100 mass% or less, 99.9 mass% or less, 99.5 mass% or less, 99.0 mass% or less, 98.5 mass% or less, 98.0 mass% or less, 97.5 mass% or less, 97.0 mass% or less, 96.5 mass% or less, or 96.0 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0022] Details of the components contained in the lubricating oil composition of one embodiment of the present invention will be described hereinafter.

<Component (A): base oil>

[0023] As the base oil that is the component (A) used in one embodiment of the present invention, one or more selected from mineral oils and synthetic oils can be mentioned.

[0024] Examples of the mineral oils include atmospheric residues obtained by subjecting crude oils, such as paraffinic crude oil, intermediate base crude oil and naphthenic crude oil, to atmospheric distillation; distillates obtained by subjecting these atmospheric residues to vacuum distillation; and refined oils obtained by subjecting the distillates to one or more of refining treatments, such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, and hydrorefining (hydrocracking).

[0025] Examples of the synthetic oils include poly-α-olefins, such as an α-olefin homopolymer and an α-olefin copolymer (for example, an α-olefin copolymer having 8 to 14 carbon atoms such as an ethylene-α-olefin copolymer); isoparaffin; polyalkylene glycol; ester oils, such as polyol ester, dibasic acid ester, and phosphoric acid ester; ether oils, such as polyphenyl ether; alkylbenzene; alkylnaphthalene; and synthetic oil (GTL) obtained by isomerizing wax (GTL WAX (Gas To Liquids WAX)) produced from natural gas through Fischer-Tropsch process or the like.

[0026] The component (A) used in one embodiment of the present invention preferably contains one or more selected from mineral oils classified in Group II and Group III of API (American Petroleum Institute) base oil categories, and synthetic oils.

[0027] The kinematic viscosity of the component (A) used in one embodiment of the present invention at 100°C is preferably 1.9 mm^2/s or more, more preferably 2.0 mm^2/s or more, more preferably 2.1 mm^2/s or more, and still more preferably 2.2 mm^2/s or more, or may be 2.3 mm^2/s or more, 2.5 mm^2/s or more, 2.7 mm^2/s or more, 2.9 mm^2/s or more, 3.0 mm^2/s or more, 3.2 mm^2/s or more, 3.4 mm^2/s or more, or 3.6 mm^2/s or more, and it is preferably 5.0 mm^2/s or less, more preferably 4.8 mm^2/s or less, more preferably 4.6 mm^2/s or less, still more preferably 4.5 mm^2/s or less, still much

more preferably 4.3 mm^2/s or less, and particularly preferably 4.2 mm^2/s or less, or may be 4.0 mm^2/or less, 3.8 mm^2/s or less, 3.7 mm^2/s or less, 3.6 mm^2/s or less, 3.5 mm^2/s or less, 3.4 mm^2/s or less, 3.3 mm^2/s or less, 3.2 mm^2/s or less, 3.0 mm^2/s or less, 2.8 mm^2/s or less, or 2.6 mm^2/s or less.

[0028] The viscosity index of the component (A) used in one embodiment of the present invention is preferably 70 or more, more preferably 80 or more, still more preferably 90 or more, and still much more preferably 100 or more.

[0029] When a mixed oil that is a combination of two or more base oils is used as the component (A) in one embodiment of the present invention, the kinematic viscosity and the viscosity index of the mixed oil are preferably in the above ranges. On that account, by using a low-viscosity base oil and a high-viscosity base oil in combination, the mixed oil may be prepared so as to have a kinematic viscosity and a viscosity index in the above ranges.

[0030] In the lubricating oil composition of one embodiment of the present invention, the content of the component (A) is preferably 45 mass% or more, more preferably 50 mass% or more, more preferably 55 mass% or more, still more preferably 60 mass% or more, still much more preferably 65 mass% or more, and particularly preferably 70 mass% or more, or may be 75 mass% or more, 80 mass% or more, 85 mass% or more, 90 mass% or more, or 92 mass% or more, and it is preferably 99.99 mass% or less, more preferably 99.90 mass% or less, more preferably 99.50 mass% or less, still more preferably 99.00 mass% or less, still much more preferably 98.50 mass% or less, and particularly preferably 98.00 mass% or less, or may be 97.50 mass% or less, 97.00 mass% or less, 96.50 mass% or less, or 96.00 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.

<Component (B): thiadiazole-based compounds

[0031] The lubricating oil composition of one embodiment of the present invention can become a lubricating oil composition having been improved in scuffing resistance by containing a thiadiazole-based compound as the component (B). The scuffing resistance improving effect of the component (B) can be more effectively exhibited even in a lubricating oil composition whose viscosity has been lowered.

[0032] The component (B) may be used singly, or may be used in combination of two or more.

[0033] However, the component (B) also causes increase in elution amount of copper and decrease in oxidation stability. On that account, in the lubricating oil composition of one embodiment of the present invention, the content of the component (B) is restricted to less than 0.60 mass% based on the total amount (100 mass%) of the lubricating oil composition. In other words, in a lubricating oil composition in which the content of the component (B) is 0.60 mass% or more, increase in elution amount of copper and decrease in oxidation stability tend to occur.

[0034] From the viewpoint of obtaining a lubricating oil composition having good copper elution suppressing effect and oxidation stability, the content of the component (B) in the lubricating oil composition of one embodiment of the present invention is less than 0.60 mass%, preferably 0.57 mass% or less, more preferably 0.55 mass% or less, more preferably 0.52 mass% or less, more preferably 0.50 mass% or less, still more preferably 0.47 mass% or less, still more preferably 0.45 mass% or less, still more preferably 0.42 mass% or less, still much more preferably 0.40 mass% or less, and particularly preferably 0.39 mass% or less, or may be 0.38 mass% or less, 0.37 mass% or less, 0.36 mass% or less, 0.35 mass% or less, 0.34 mass% or less, 0.33 mass% or less, or 0.32 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0035] From the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance, the content of the component (B) in the lubricating oil composition of one embodiment of the present invention is preferably 0.01 mass% or more, more preferably 0.05 mass% or more, more preferably 0.07 mass% or more, more preferably 0.10 mass% or more, still more preferably 0.12 mass% or more, still more preferably 0.15 mass% or more, still more preferably 0.17 mass% or more, still much more preferably 0.20 mass% or more, and particularly preferably 0.22 mass% or more, or may be 0.23 mass% or more, 0.24 mass% or more, 0.25 mass% or more, 0.26 mass% or more, 0.27 mass% or more, or 0.28 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition.

[0036] From the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance, the content of the component (B) in terms of sulfur atoms in the lubricating oil composition of one embodiment of the present invention is preferably 30 ppm by mass or more, more preferably 50 ppm by mass or more, more preferably 100 ppm by mass or more, more preferably 150 ppm by mass or more, still more preferably 200 ppm by mass or more, still more preferably 250 ppm by mass or more, still more preferably 300 ppm by mass or more, still much more preferably 400 ppm by mass or more, and particularly preferably 500 ppm by mass or more, or may be 600 ppm by mass or more, 650 ppm by mass or more, 700 ppm by mass or more, 750 ppm by mass or more, 800 ppm by mass or more, 850 ppm by mass or more, 900 ppm by mass or more, 950 ppm by mass or more, or 1000 ppm by mass or more, and from the viewpoint of obtaining a lubricating oil composition having good copper elution suppressing effect and oxidation stability, it is preferably 2500 ppm by mass or less, more preferably 2000 ppm by mass or less, more preferably 1900 ppm by mass or less, more preferably 1800 ppm by mass or less, still more preferably 1700 ppm by mass or less, still more preferably 1600 ppm by mass or less, still more preferably 1500 ppm by mass or less, still much more preferably 1400 ppm by mass or less, and particularly preferably 1300 ppm by mass or less, or may be 1250 ppm by mass or less, 1200

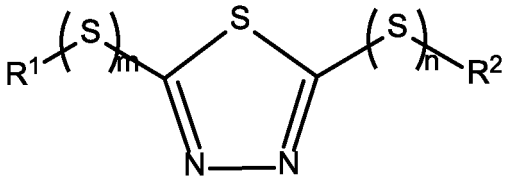
ppm by mass or less, 1150 ppm by mass or less, 1100 ppm by mass or less, or 1050 ppm by mass or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0037] From the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance, the content of the component (B) in terms of nitrogen atoms in the lubricating oil composition of one embodiment of the present invention is preferably 10 ppm by mass or more, more preferably 30 ppm by mass or more, more preferably 50 ppm by mass or more, more preferably 60 ppm by mass or more, still more preferably 70 ppm by mass or more, still more preferably 80 ppm by mass or more, still more preferably 90 ppm by mass or more, still much more preferably 100 ppm by mass or more, and particularly preferably 120 ppm by mass or more, or may be 130 ppm by mass or more, 140 ppm by mass or more, 150 ppm by mass or more, 160 ppm by mass or more, 170 ppm by mass or more, 180 ppm by mass or more, or 190 ppm by mass or more, and from the viewpoint of obtaining a lubricating oil composition having good copper elution suppressing effect and oxidation stability, it is preferably 500 ppm by mass or less, more preferably 450 ppm by mass or less, more preferably 400 ppm by mass or less, more preferably 350 ppm by mass or less, still more preferably 320 ppm by mass or less, still more preferably 300 ppm by mass or less, still more preferably 290 ppm by mass or less, still much more preferably 280 ppm by mass or less, and particularly preferably 270 ppm by mass or less, or may be 260 ppm by mass or less, 250 ppm by mass or less, 240 ppm by mass or less, 230 ppm by mass or less, 220 ppm by mass or less, 210 ppm by mass or less, or 200 ppm by mass or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0038] The thiadiazole-based compound that is the component (B) used in one embodiment of the present invention may be any compound as long as it is a compound having a thiadiazole ring, but from the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance, it preferably contains a compound represented by any one of the following general formulae (b-1) to (b-4), and more preferably contains at least a compound represented by the following general formula (b-1).

[0039] The component (B) may be used singly, or may be used in combination of two or more.

[0040]



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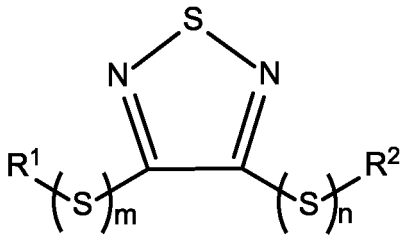

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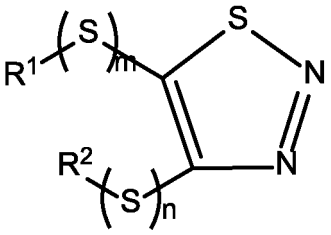

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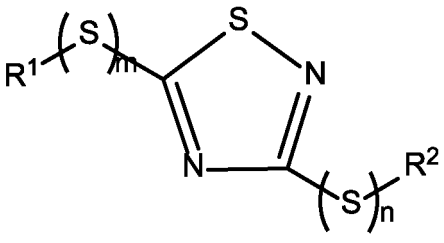


(b-4)

[0041] In the above formulae, R^1 and R^2 are each independently a hydrocarbon group.

[0042] m and n are each independently an integer of 1 to 10, but from the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance, they are each independently preferably an integer of 1 to 6, more preferably an integer of 1 to 4, still more preferably an integer of 2 to 3, and still much more preferably 2.

[0043] Examples of the hydrocarbon groups capable of being selected as R^1 and R^2 include straight-chain or branched chain alkyl groups, such as a methyl group, an ethyl group, a propyl group (n-propyl group, isopropyl group), a butyl group (n-butyl group, s-butyl group, t-butyl group, isobutyl group), a pentyl group, a hexyl group, a heptyl group, an octyl group, a 2-ethylhexyl group, a nonyl group, a 1,1-dimethylheptyl 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; straight-chain or branched chain alkenyl groups, such as an ethenyl group, a propenyl group, a butenyl group, a pentenyl group, a hexenyl group, a heptenyl group, an octenyl group, a nonenyl group, a decenyl group, an undecenyl group, a dodecenyl group, a tridecenyl group, a tetradecenyl group and a pentadecenyl group; cycloalkyl groups which may have an alkyl group, such as a cyclohexyl group, a dimethylcyclohexyl group, an ethylcyclohexyl group, a propylcyclohexyl group, a butylcyclohexyl group and a heptylcyclohexyl group; aryl groups, such as a phenyl group, a naphthyl group, an anthracenyl group, a biphenyl group and a terphenyl group; alkylaryl groups, such as a tolyl group, a dimethylphenyl group, a butylphenyl group, a nonylphenyl group, a methylbenzyl group, and a dimethylnaphthyl group; and arylalkyl groups, such as a phenylmethyl group, a phenylethyl group and a diphenylmethyl group.

[0044] From the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance, the number of carbon atoms of the hydrocarbon group capable of being selected as R^1 and R^2 is preferably 1 or more, more preferably 2 or more, still more preferably 3 or more, and still much more preferably 5 or more, or may be 7 or more, 8 or more, or 9 or more, and it is preferably 30 or less, more preferably 24 or less, more preferably 20 or less, more preferably 18 or less, still more preferably 16 or less, still more preferably 14 or less, and still much more preferably 12 or less, or may be 11 or less, or 10 or less.

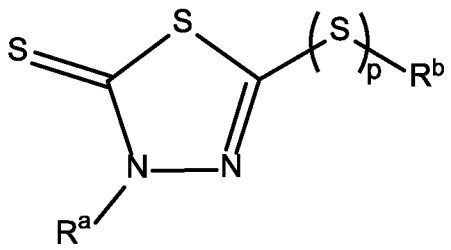
[0045] From the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance, R^1 and R^2 are each independently preferably an alkyl group among these, and from the viewpoint of obtaining a lubricating oil composition capable of effectively suppressing elution of copper by being improved in copper corrosion prevention together with scuffing resistance, they are each independently more preferably a branched chain alkyl group, and still more preferably a branched chain alkyl group having 5 or more carbon atoms.

[0046] From the above viewpoint, the number of carbon atoms of the branched chain alkyl group is preferably 5 or more, but it is more preferably 7 or more, still more preferably 8 or more, and still much more preferably 9 or more, and it is preferably 30 or less, more preferably 24 or less, more preferably 20 or less, more preferably 18 or less, still more preferably 16 or less, still more preferably 14 or less, and still much more preferably 12 or less, or may be 11 or less, or 10 or less.

[0047] In the lubricating oil composition of one embodiment of the present invention, the total content of the compounds each of which is represented by any one of the general formulae (b-1) to (b-4) is preferably 60 to 100 mass%, more preferably 70 to 100 mass%, still more preferably 80 to 100 mass%, still much more preferably 90 to 100 mass%, and particularly preferably 95 to 100 mass%, based on the total amount (100 mass%) of the component (B) contained in the lubricating oil composition, from the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance.

[0048] In the lubricating oil composition of one embodiment of the present invention, the content of the compound represented by the general formula (b-1) is preferably 50 to 100 mass%, more preferably 60 to 100 mass%, still more preferably 70 to 100 mass%, still much more preferably 80 to 100 mass%, and particularly preferably 90 to 100 mass%, based on the total amount (100 mass%) of the component (B) contained in the lubricating oil composition, from the above viewpoint.

[0049] In the lubricating oil composition of one embodiment of the present invention, the content of a compound represented by the following general formula (b-x) is preferably less than 10 mass%, more preferably less than 8 mass%, still more preferably less than 5 mass%, still much more preferably less than 3 mass%, and particularly preferably less than 1 mass%, based on the total amount (100 mass%) of the component (B) contained in the lubricating oil composition.



(b-x)

wherein R^a is a hydrogen atom or a methyl group, R^b is an alkyl group having 1 to 4 carbon atoms, and p is 0 or 1.

[0050] In the lubricating oil composition of the present invention, the component (B) preferably contains a thiadiazole-based compound (B1) having a branched chain alkyl group (also referred to as a "component (B1)" hereinafter), from the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance and having good copper elution suppressing effect.

[0051] From the above viewpoint, the content of the component (B1) is preferably 50 to 100 mass%, more preferably 60 to 100 mass%, more preferably 70 to 100 mass%, still more preferably 80 to 100 mass%, still much more preferably

90 to 100 mass%, and particularly preferably 95 to 100 mass%, based on the total amount (100 mass%) of the component (B) contained in the lubricating oil composition.

[0052] From the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance and having good copper elution suppressing effect, the number of carbon atoms of the branched chain alkyl group of the component (B1) is preferably 5 or more, more preferably 7 or more, still more preferably 8 or more, and still much more preferably 9 or more, and it is preferably 30 or less, more preferably 24 or less, more preferably 20 or less, more preferably 18 or less, still more preferably 16 or less, still more preferably 14 or less, and still much more preferably 12 or less, or may be 11 or less, or 10 or less.

[0053] From the viewpoint of obtaining a lubricating oil composition having been more improved in scuffing resistance and having good copper elution suppressing effect, the component (B1) is preferably a compound represented by any one of the general formulae (b-1) to (b-4) wherein R^1 and R^2 are each independently a branched chain alkyl group, and is more preferably a compound represented by the general formula (b-1) wherein R^1 and R^2 are each independently a branched chain alkyl group. A preferred range of the number of carbon atoms of the branched chain alkyl group is as previously described.

<Sulfurized olefin>

[0054] The lubricating oil composition of one embodiment of the present invention may contain a sulfurized olefin as long as the effects of the present invention are not impaired. However, the content of the sulfurized olefin is preferably as small as possible, from the viewpoint of obtaining a lubricating oil composition having good scuffing resistance, copper elution suppressing effect, oxidation stability and insulation properties.

[0055] From the above viewpoint, the content of the sulfurized olefin in the lubricating oil composition of one embodiment of the present invention is preferably less than 0.20 mass%, more preferably less than 0.18 mass%, more preferably less than 0.15 mass%, still more preferably less than 0.12 mass%, still much more preferably less than 0.10 mass%, and particularly preferably less than 0.07 mass%, or may be less than 0.05 mass%, less than 0.04 mass%, less than 0.03 mass%, less than 0.02 mass%, less than 0.01 mass%, or less than 0.001 mass%, based on the total amount (100 mass%) of the lubricating oil composition.

[0056] As the sulfurized olefin, for example, a compound represented by the following general formula (i) can be mentioned.

$$R\text{-}(S)_q\text{-}R' \qquad (i)$$

[0057] In the formula (i), R is an alkenyl group having 2 to 20 carbon atoms, R' is an alkenyl group having 2 to 20 carbon atoms or an alkyl group having 2 to 20 carbon atoms, and q is an integer of 1 to 10.

<Component (C): boron-modified alkenyl succinimide>

[0058] The lubricating oil composition of one embodiment of the present invention contains a boron-modified alkenyl succinimide as the component (C). As previously described, the component (B) contributes to improvement in scuffing resistance, but at the same time, it also causes increase in elution amount of copper and decrease in oxidation stability. Therefore, by incorporating the component (C) together with the component (B) in the lubricating oil composition of one embodiment of the present invention, a lubricating oil composition having excellent copper elution suppressing effect and oxidation stability while exhibiting excellent scuffing resistance is obtained.

[0059] The component (C) may be used singly, or may be used in combination of two or more.

[0060] In the lubricating oil composition of one embodiment of the present invention, the component (C) satisfies the following requirements (I) and (II). Requirement (I): a content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) is 0.35 or more.

Requirement (II): a content of boron atoms derived from the component (C) is 300 ppm by mass or less based on the total amount of the lubricating oil composition.

[0061] By setting the content ratio [B/N] to 0.35 or more to meet the requirement (I), a lubricating oil composition having been improved in copper elution suppressing effect and oxidation stability can be obtained. In contrast, a lubricating oil composition having the content ratio [B/N] of less than 0.35 is inferior in copper elution suppressing effect and oxidation stability.

[0062] Furthermore, by adjusting the content of boron atoms derived from the component (C) to meet the requirement (II), a lubricating oil composition favorably maintaining scuffing resistance and insulation properties can be obtained. In other words, a lubricating oil composition in which a content of boron atoms derived from the component (C) is more than 300 ppm by mass is inferior in scuffing resistance and insulation properties.

[0063] From the viewpoint of obtaining a lubricating oil composition having been more improved in copper elution

suppressing effect and oxidation stability, the content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) in the lubricating oil composition of one embodiment of the present invention is 0.35 or more as specified in the requirement (1), preferably 0.40 or more, more preferably 0.45 or more, more preferably 0.50 or more, more preferably 0.55 or more, still more preferably 0.60 or more, still more preferably 0.65 or more, still more preferably 0.70 or more, still much more preferably 0.75 or more, and particularly preferably 0.80 or more, or may be 0.85 or more, or 0.90 or more.

[0064] The content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) may be 2.0 or less, 1.9 or less, 1.8 or less, 1.7 or less, 1.6 or less, 1.5 or less, 1.4 or less, or 1.3 or less.

[0065] From the viewpoint of obtaining a lubricating oil composition favorably maintaining scuffing resistance and insulation properties, the content of boron atoms derived from the component (C) in the lubricating oil composition of one embodiment of the present invention is 300 ppm by mass or less, preferably 280 ppm by mass or less, more preferably 250 ppm by mass or less, more preferably 220 ppm by mass or less, more preferably 200 ppm by mass or less, still more preferably 180 ppm by mass or less, still more preferably 160 ppm by mass or less, still more preferably 150 ppm by mass or less, still much more preferably 140 ppm by mass or less, and particularly preferably 130 ppm by mass or less, or may be 125 ppm by mass or less, 120 ppm by mass or less, 115 ppm by mass or less, or 110 ppm by mass or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0066] From the viewpoint of obtaining a lubricating oil composition having excellent copper elution suppressing effect and oxidation stability, the content of boron atoms derived from the component (C) is preferably 3.0 ppm by mass or more, more preferably 5.0 ppm by mass or more, more preferably 7.0 ppm by mass or more, more preferably 10.0 ppm by mass or more, still more preferably 12.0 ppm by mass or more, still more preferably 15.0 ppm by mass or more, still more preferably 17.0 ppm by mass or more, still much more preferably 20.0 ppm by mass or more, and particularly preferably 22.0 ppm by mass or more, or may be 25.0 ppm by mass or more, 30.0 ppm by mass or more, 35.0 ppm by mass or more, 40.0 ppm by mass or more, 45.0 ppm by mass or more, 50.0 ppm by mass or more, 55.0 ppm by mass or more, 60.0 ppm by mass or more, 65.0 ppm by mass or more, 70.0 ppm by mass or more, or 75.0 ppm by mass or more, based on the total amount (100 mass%) of the lubricating oil composition.

[0067] From the viewpoint of obtaining a lubricating oil composition favorably maintaining scuffing resistance and insulation properties and having excellent copper elution suppressing effect and oxidation stability, the content of nitrogen atoms derived from the component (C) in the lubricating oil composition of one embodiment of the present invention is preferably 5.0 ppm by mass or more, more preferably 7.0 ppm by mass or more, more preferably 9.0 ppm by mass or more, more preferably 10.0 ppm by mass or more, still more preferably 12.0 ppm by mass or more, still more preferably 15.0 ppm by mass or more, still more preferably 17.0 ppm by mass or more, still much more preferably 20.0 ppm by mass or more, and particularly preferably 22.0 ppm by mass or more, or may be 25.0 ppm by mass or more, 30.0 ppm by mass or more, 35.0 ppm by mass or more, 40.0 ppm by mass or more, 45.0 ppm by mass or more, 50.0 ppm by mass or more, 55.0 ppm by mass or more, 60.0 ppm by mass or more, 65.0 ppm by mass or more, 70.0 ppm by mass or more, 75.0 ppm by mass or more, 80.0 ppm by mass or more, or 85.0 ppm by mass or more, and it is preferably 320 ppm by mass or less, more preferably 300 ppm by mass or less, more preferably 280 ppm by mass or less, more preferably 250 ppm by mass or less, still more preferably 220 ppm by mass or less, still more preferably 200 ppm by mass or less, still more preferably 180 ppm by mass or less, still much more preferably 160 ppm by mass or less, and particularly preferably 150 ppm by mass or less, or may be 140 ppm by mass or less, 135 ppm by mass or less, 130 ppm by mass or less, 125 ppm by mass or less, 120 ppm by mass or less, 115 ppm by mass or less, 110 ppm by mass or less, 105 ppm by mass or less, or 100 ppm by mass or less, based on the total amount (100 mass%) of the lubricating oil composition.

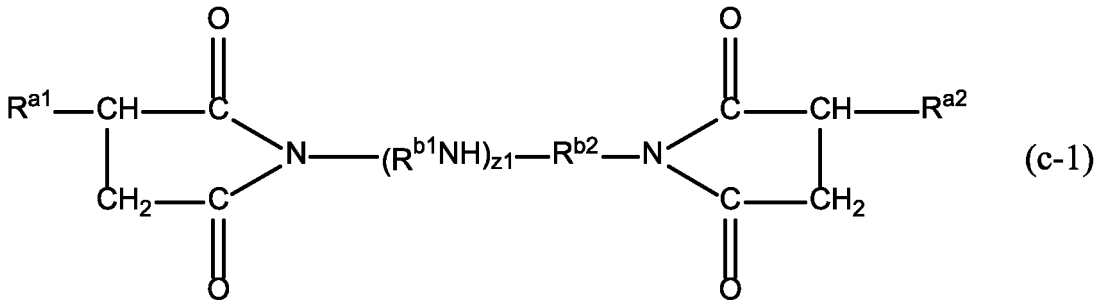
[0068] As the component (C) used in one embodiment of the present invention, one or more selected from a boron-modified alkenyl bis-succinimide (C1) and a boron-modified alkenyl monosuccinimide (C2) can be mentioned.

[0069] From the viewpoint of obtaining a lubricating oil composition having excellent copper elution suppressing effect and oxidation stability while exhibiting excellent scuffing resistance, the component (C) used in one embodiment of the present invention preferably contains a boron-modified alkenyl bis-succinimide (C1).

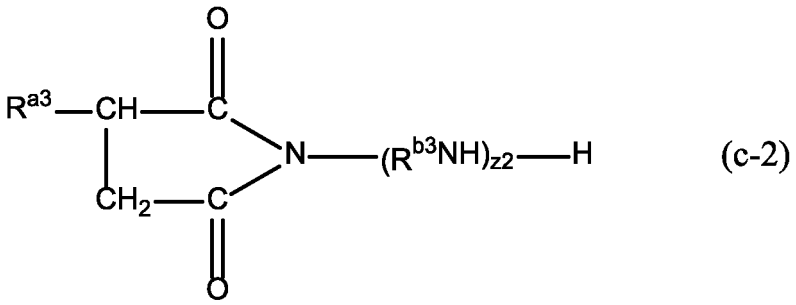
[0070] From the above viewpoint, the content of the component (C1) is preferably 20 to 100 mass%, more preferably 40 to 100 mass%, more preferably 50 to 100 mass%, still more preferably 60 to 100 mass%, still more preferably 70 to 100 mass%, still much more preferably 80 to 100 mass%, and particularly preferably 90 to 100 mass%, based on the total amount (100 mass%) of the component (C) contained in the lubricating oil composition.

[0071] As the component (C1), a boron-modified product of a compound represented by the aforementioned general formula (c-1) can be mentioned. As the component (C2), a boron-modified product of a compound represented by the aforementioned general formula (c-2) can be mentioned.

[0072]



(c-1)



(c-2)

[0073] In the general formulae (c-1) and (c-2), R^{a1}, R^{a2} and R^{a3} are each independently an alkenyl group having a mass-average molecular weight (Mw) of 500 to 3000 (preferably 900 to 2500).

[0074] Examples of the alkenyl groups capable of being selected as R^{a1}, R^{a2} and R^{a3} include a polybutenyl group, a polyisobutenyl group and an ethylene-propylene copolymer, and among these, a polybutenyl group or a polyisobutenyl group is preferable.

[0075] R^{b1}, R^{b2} and R^{b3} are each independently an alkylene group having 2 to 5 carbon atoms.

[0076] z1 is an integer of 0 to 10, preferably an integer of 1 to 4, and more preferably 2 or 3.

[0077] z2 is an integer of 1 to 10, preferably an integer of 2 to 5, and more preferably 3 or 4.

<Ashless dispersant other than component (C)>

[0078] The lubricating oil composition of one embodiment of the present invention may contain an ashless dispersant other than the component (C) as long as the effects of the present invention are not impaired.

[0079] As the ashless dispersants other than the component (C), a non-boron modified alkenyl succinimide and an alkenyl succinimide modified with a substance other than boron can be mentioned.

[0080] Examples of the non-boron modified alkenyl succinimide include an alkenyl bis-succinimide represented by the aforementioned general formula (c-1) and an alkenyl monosuccinimide represented by the aforementioned general formula (c-2).

[0081] Examples of the alkenyl succinimide modified with a substance other than boron include reaction products obtained by reacting a compound represented by the aforementioned general formula (c-1) or (c-2) with one or more selected from an alcohol, an aldehyde, a ketone, an alkylphenol, a cyclic carbonate, an epoxy compound, an organic acid, and the like.

[0082] In the lubricating oil composition of one embodiment of the present invention, the content of the ashless dispersant other than the component (C) may be 10.0 mass% or less, 8.0 mass% or less, 6.0 mass% or less, 5.0 mass% or less, 4.0 mass% or less, 3.0 mass% or less, 2.0 mass% or less, 1.0 mass% or less, 0.7 mass% or less, 0.5 mass% or less, 0.3 mass% or less, 0.2 mass% or less, or 0.1 mass% or less, and it may be 0 mass% or more, 0.001 mass% or more, or 0.1 mass% or more, based on the total amount (100 mass%) of the lubricating oil composition.

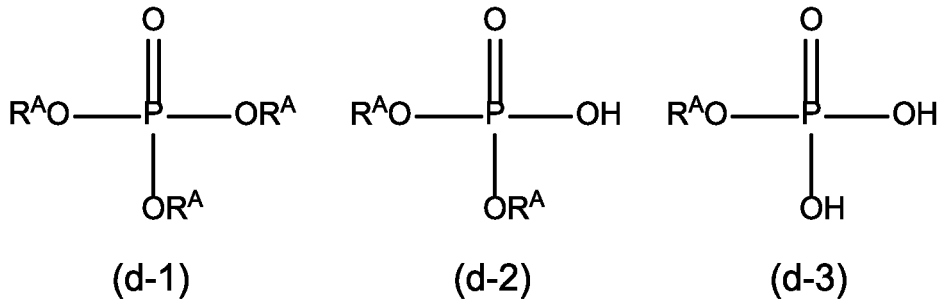
<Component (D): phosphorus-based compound>

[0083] The lubricating oil composition of one embodiment of the present invention preferably further contains one or more phosphorus-based compounds (D) selected from a phosphoric acid ester and a phosphorous acid ester, from the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance.

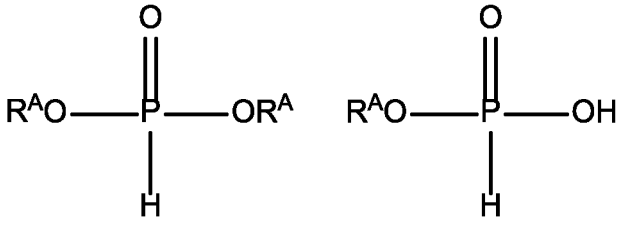
[0084] Examples of the phosphoric acid ester used as the component (D) in one embodiment of the present invention include a neutral phosphoric acid ester represented by the following general formula (d-1) and an acidic phosphoric acid ester represented by the following general formula (d-2) or (d-3).

[0085] Examples of the phosphorous acid ester used as the component (D) in one embodiment of the present invention include an acidic phosphorous acid ester represented by the following general formula (d-4) or (d-5).

[0086]



(d-1) (d-2) (d-3)



(d-4) (d-5)

[0087] In the above formulae, each R^A is independently an alkyl group having 1 to 30 carbon atoms, an alkenyl group having 2 to 20 carbon atoms, an aryl group having 6 to 18 carbon atoms which may be substituted by an alkyl group having 1 to 6 carbon atoms, a group having a sulfide bond, or the like. Multiple R^A may be the same as one another, or may be different from one another.

[0088] Examples of the alkyl groups capable of being selected as R^A include a methyl group, an ethyl group, a propyl group (n-propyl group, isopropyl group), a butyl group (n-butyl group, s-butyl group, t-butyl group, isobutyl group), a pentyl group, a hexyl group, a 2-ethylhexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, an undecyl group, a dodecyl group, tridecyl group, a tetradecyl group, a hexadecyl group and an octadecyl group.

[0089] These alkyl groups may be straight-chain alkyl groups or may be branched chain alkyl groups.

[0090] The number of carbon atoms of the alkyl group is 1 to 30, but it is preferably 3 to 20, more preferably 5 to 16, still more preferably 6 to 14, and still much more preferably 8 to 12.

[0091] Examples of the alkenyl groups capable of being selected as R^A include an ethenyl group, a propenyl group, a butenyl group, a pentenyl group, a hexenyl group, a heptenyl group, an octenyl group, a nonenyl group, a decenyl group, an undecenyl group, a dodecenyl group, a tridecenyl group, a tetradecenyl group, a pentadecenyl group, a hexadecenyl group and an octadecenyl group.

[0092] These alkenyl groups may be straight-chain alkenyl groups or may be branched chain alkenyl groups.

[0093] The number of carbon atoms of the alkenyl group is 2 to 20, but it is preferably 3 to 16, and more preferably 6 to 12.

[0094] Examples of the aryl groups capable of being selected as R^A include a phenyl group, a naphthyl group, an anthryl group, a phenanthryl group, a biphenyl group, a terphenyl group and a phenylnaphthyl group, and preferable is a phenyl group.

[0095] Examples of the "alkyl group having 1 to 6 carbon atoms" that can substitute these aryl groups include alkyl groups having 1 to 6 carbon atoms among the aforementioned alkyl groups.

[0096] The group having a sulfide bond, which is capable of being selected as R^A, is preferably a group represented by the following general formula (ii).

$$*\text{-}R^{A02}\text{-}S_x\text{-}R^{A01} \qquad \text{(ii)}$$

[0097] In the formula (ii), R^{A01} is a hydrogen atom or a monovalent organic group having 1 to 20 carbon atoms. R^{A02} is a divalent organic group, x is an integer of 1 or more, preferably an integer of 1 to 10, more preferably an integer of 1 to 5, still more preferably an integer of 1 to 3, still much more preferably 1 or 2, and particularly preferably 1. * represents a bonding position.

[0098] Examples of the monovalent organic groups capable of being selected as R^{A01} include an alkyl group, an

alkenyl group and an aryl group, and preferable is an alkyl group having 1 to 20 carbon atoms or a group wherein at least one $-CH_2-$ structure of an alkyl group having 1 to 20 (preferably 2 to 18, more preferably 4 to 16, still more preferably 6 to 12, still much more preferably 8 to 10) carbon atoms has been substituted by -O-, -S-, -COO-, -OCO-, -CSO-, -OCS-, -CH=CH- or -C=C-, and more preferable is an alkyl group.

[0099] The alkyl group capable of being selected as R^{A01} may be a straight-chain alkyl group or may be a branched chain alkyl group, but it is preferably a straight-chain alkyl group.

[0100] The number of carbon atoms of the alkyl group is 1 to 20, but it is preferably 2 to 18, more preferably 4 to 16, still more preferably 6 to 12, and still much more preferably 8 to 10.

[0101] Examples of the divalent organic groups capable of being selected as R^{A02} include an alkylene group having 1 to 20 carbon atoms, a cycloalkylene group, an alkenylene group having 1 to 20 carbon atoms, a cycloalkenylene group and an arylene group, and preferable is an alkylene group having 1 to 20 carbon atoms or a group wherein at least one $-CH_2-$ structure of an alkylene group having 1 to 20 (preferably 2 to 12, more preferably 2 to 8, still more preferably 2 to 4) carbon atoms has been substituted by -O-, -S-, -COO-, -OCO-, -CSO-, -OCS-, -CH=CH- or -C=C-, and more preferable is an alkylene group having 2 to 20 carbon atoms.

[0102] The alkylene group capable of being selected as R^{A02} may be a straight-chain alkylene group or may be a branched chain alkylene group, but it is preferably a straight-chain alkylene group.

[0103] The number of carbon atoms of the alkylene group is 1 to 20, but it is preferably 1 to 12, more preferably 1 to 8, still more preferably 1 to 4, still much more preferably 1, 2 or 4, and particularly preferably 2.

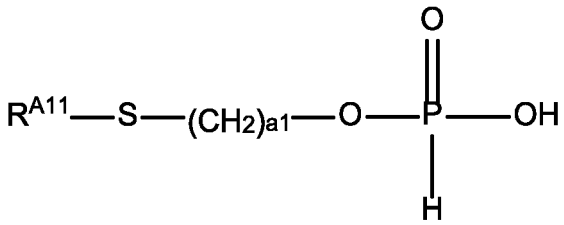
[0104] In the lubricating oil composition of one embodiment of the present invention, the component (D) preferably contains one or more sulfur-phosphorus-based compounds (D1) selected from a sulfur atom-containing phosphoric acid ester and a sulfur atom-containing phosphorous acid ester, from the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance.

[0105] In the lubricating oil composition of one embodiment of the present invention, the content of the component (D1) is preferably 60 to 100 mass%, more preferably 70 to 100 mass%, more preferably 80 to 100 mass%, still more preferably 90 to 100 mass%, still much more preferably 95 to 100 mass%, and particularly preferably 98 to 100 mass%, based on the total amount (100 mass%) of the component (D) contained in the lubricating oil composition, from the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance.

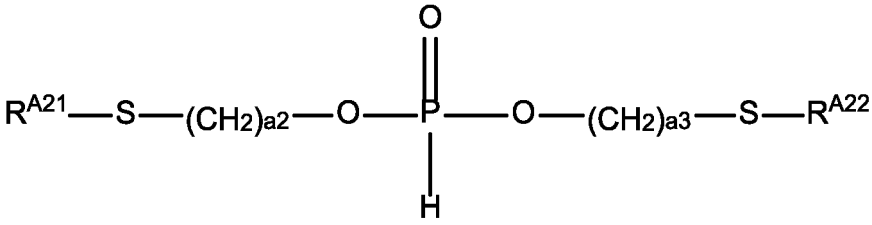
[0106] As the sulfur atom-containing phosphoric acid ester and the sulfur atom-containing phosphorous acid ester, a sulfur atom-containing phosphoric acid ester and a sulfur atom-containing phosphorous acid ester each of which has a group represented by the aforementioned formula (ii) can be mentioned.

[0107] From the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance, the component (D1) used in one embodiment of the present invention is preferably a sulfur atom-containing phosphorus acid ester having a group represented by the formula (ii), and is more preferably one or more selected from a compound (D11) represented by the following general formula (d-11) and a compound (D12) represented by the following general formula (d-12).

[0108]



(d-11)



(d-12)

[0109] In the formulae (d-11) and (d-12), R^{A11}, R^{A21} and R^{A22} are each independently a hydrogen atom or an alkyl group having 1 to 20 carbon atoms.

[0110] The alkyl group may be a straight-chain alkyl group or may be a branched chain alkyl group, but it is preferably

a straight-chain alkyl group.

[0111] The number of carbon atoms of the alkyl group is 1 to 20, but it is preferably 2 to 18, more preferably 4 to 16, still more preferably 6 to 12, and still much more preferably 8 to 10.

[0112] a1, a2 and a3 are each independently an integer of 1 to 20, but preferably an integer of 1 to 12, more preferably an integer of 1 to 8, still more preferably an integer of 1 to 4, still much more preferably 1, 2 or 4, and particularly preferably 2.

[0113] In the lubricating oil composition of one embodiment of present invention, the component (D) still more preferably contains both of the compound (D11) represented by the general formula (d-11) and the compound (D12) represented by the general formula (d-12), from the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance.

[0114] In one embodiment of the present invention, the content ratio by mass of the compound (D11) to the compound (D12), [(D11)/(D12)], is preferably 1/20 to 20/1, more preferably 1/16 to 10/1, more preferably 1/14 to 5/1, still more preferably 1/12 to 2/1, still much more preferably 1/11 to 1/1, and particularly preferably 1/10 to 1/2.

[0115] The acid phosphoric acid ester and the acid phosphorous acid ester each of which is used as the component (D) in one embodiment of the present invention may be each in the form of an amine salt.

[0116] The amine to form the amine salt is preferably a compound represented by the following general formula (d-i). The amine may be used singly, or may be used in combination of two or more.

$$(R^x)_r\text{-}N\text{-}(H)_{3-r} \qquad \text{(d-i)}$$

[0117] In the general formula (d-i), r is an integer of 1 to 3, and is preferably 1.

[0118] Each R^x is independently an alkyl group having 6 to 18 carbon atoms, an alkenyl group having 6 to 18 carbon atoms, an aryl group having 6 to 18 carbon atoms, or a hydroxyalkyl group having 6 to 18 carbon atoms.

[0119] When multiple R^x are present, the multiple R^x may be the same as one another, or may be different from one another.

[0120] Examples of the alkyl group having 6 to 18 carbon atoms, the alkenyl group having 6 to 18 carbon atoms and the aryl group having 6 to 18 carbon atoms capable of being selected as R^x include groups having carbon atoms of the above ranges among the groups given as examples of the alkyl group, the alkenyl group and the aryl group capable of being selected as R^{21} to R^{23}.

[0121] As the hydroxyalkyl group having 6 to 18 carbon atoms, a group wherein a hydrogen atom of an alkyl group having 6 to 18 carbon atoms is substituted by a hydroxyl group can be mentioned, and specific examples thereof include a hydroxyhexyl group, a hydroxyoctyl group, a hydroxydodecyl group and a hydroxytridecyl group.

[0122] From the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance, the content of the component (D) in the lubricating oil composition of one embodiment of the present invention is preferably 0.01 mass% or more, more preferably 0.05 mass% or more, still more preferably 0.07 mass% or more, still much more preferably 0.10 mass% or more, and particularly preferably 0.15 mass% or more, or may be 0.17 mass% or more, 0.20 mass% or more, 0.23 mass% or more, 0.25 mass% or more, 0.27 mass% or more, or 0.30 mass% or more, and it is preferably 3.0 mass% or less, more preferably 2.5 mass% or less, still more preferably 2.0 mass% or less, still much more preferably 1.5 mass% or less, and particularly preferably 1.2 mass% or less, or may be 1.0 mass% or less, 0.95 mass% or less, 0.90 mass% or less, 0.85 mass% or less, 0.80 mass% or less, 0.75 mass% or less, 0.70 mass% or less, 0.65 mass% or less, 0.60 mass% or less, 0.55 mass% or less, or 0.50 mass% or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0123] From the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance, the content of the component (D) in terms of phosphorus atoms in the lubricating oil composition of one embodiment of the present invention is preferably 30 ppm by mass or more, more preferably 50 ppm by mass or more, more preferably 70 ppm by mass or more, more preferably 100 ppm by mass or more, still more preferably 120 ppm by mass or more, still more preferably 150 ppm by mass or more, still more preferably 180 ppm by mass or more, still much more preferably 200 ppm by mass or more, still much more preferably 220 ppm by mass or more, still much more preferably 250 ppm by mass or more, and particularly preferably 270 ppm by mass or more, and is preferably 800 ppm by mass or less, more preferably 700 ppm by mass or less, still more preferably 600 ppm by mass or less, still much more preferably 500 ppm by mass or less, and particularly preferably 450 ppm by mass or less, or may be 420 ppm by mass or less, 400 ppm by mass or less, 380 ppm by mass or less, 370 ppm by mass or less, 360 ppm by mass or less, or 350 ppm by mass or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0124] From the viewpoint of obtaining a lubricating oil composition having been further improved in wear resistance, the content of the component (D) in terms of sulfur atoms in the lubricating oil composition of one embodiment of the present invention is preferably 50 ppm by mass or more, more preferably 70 ppm by mass or more, more preferably 100 ppm by mass or more, more preferably 120 ppm by mass or more, still more preferably 150 ppm by mass or more, still more preferably 180 ppm by mass or more, still more preferably 200 ppm by mass or more, still much more preferably 220 ppm by mass or more, still much more preferably 250 ppm by mass or more, still much more preferably 270 ppm

by mass or more, and particularly preferably 300 ppm by mass or more, and is preferably 800 ppm by mass or less, more preferably 700 ppm by mass or less, still more preferably 600 ppm by mass or less, still much more preferably 500 ppm by mass or less, and particularly preferably 450 ppm by mass or less, or may be 420 ppm by mass or less, 400 ppm by mass or less, 380 ppm by mass or less, 370 ppm by mass or less, 360 ppm by mass or less, or 350 ppm by mass or less, based on the total amount (100 mass%) of the lubricating oil composition.

[0125] In the lubricating oil composition of one embodiment of the present invention, the content of a sulfur atom-free acid phosphoric acid ester in terms of phosphorus atoms may be less than 100 ppm by mass, less than 50 ppm by mass, less than 10 ppm by mass, less than 8 ppm by mass, less than 5 ppm by mass, less than 3 ppm by mass, or less than 1 ppm by mass, based on the total amount (100 mass%) of the lubricating oil composition.

[0126] In the lubricating oil composition of one embodiment of the present invention, the content of a sulfur atom-free neutral phosphoric acid ester in terms of phosphorus atoms may be less than 50 ppm by mass, less than 10 ppm by mass, less than 8 ppm by mass, less than 5 ppm by mass, less than 3 ppm by mass, or less than 1 ppm by mass, based on the total amount (100 mass%) of the lubricating oil composition.

<Various additives other than components (B) to (D)>

[0127] The lubricating oil composition of one embodiment of the present invention may contain various additives other than the components (B) to (D) when needed as long as the effects of the present invention are not impaired.

[0128] Examples of such various additives include a pour point depressant, an antioxidant, a metal-based detergent, a metal deactivator, a friction modifier, an anti-rust agent, and an anti-foaming agent.

[0129] These lubricating oil additives may be each used singly, or may be each used in combination of two or more.

[0130] The contents of these lubricating oil additives can be each appropriately adjusted as long as the effects of the present invention are not impaired, and the contents of the additives are each independently usually 0.001 to 15 mass%, preferably 0.005 to 10 mass%, and more preferably 0.01 to 5 mass%, based on the total amount (100 mass%) of the lubricating oil composition.

[Pour point depressant]

[0131] The lubricating oil composition of one embodiment of the present invention may further contain a pour point depressant. The pour point depressant may be used singly, or may be used in combination of two or more.

[0132] Examples of the pour point depressants used in one embodiment of the present invention include an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and naphthalene, a condensate of chlorinated paraffin and phenol, polymethacrylate, and polyalkylstyrene.

[Antioxidant]

[0133] The lubricating oil composition of one embodiment of the present invention may further contain an antioxidant. The antioxidant may be used singly, or may be used in combination of two or more.

[0134] Examples of the antioxidants used in one embodiment of the present invention include amine-based antioxidants, such as alkylated diphenylamine, phenylnaphthylamine, and alkylated phenylnaphthylamine; and phenol-based antioxidants, such as 2,6-di-t-butylphenol, 4,4'-methylenebis(2,6-di-t-butylphenol), isooctyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate, and n-octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate.

[0135] In the lubricating oil composition of one embodiment of the present invention, it is preferable to use, as the antioxidant, a combination of an amine-based antioxidant and a phenol-based antioxidant.

[Metal-based detergent]

[0136] The lubricating oil composition of one embodiment of the present invention may further contain a metal-based detergent. The metal-based detergent may be used singly, or may be used in combination of two or more.

[0137] Examples of the metal-based detergents used in one embodiment of the present invention include metal salts, such as a metal sulfonate, a metal salicylate, and a metal phenate. The metal to constitute the metal salts is preferably a metal atom selected from alkali metals and alkaline earth metals, more preferably sodium, calcium, magnesium or barium, and still more preferably calcium.

[0138] In the lubricating oil composition of one embodiment of the present invention, the metal-based detergent preferably contains one or more selected from calcium sulfonate, calcium salicylate and calcium phenate, and more preferably contains calcium sulfonate.

[0139] The content of the calcium sulfonate is preferably 50 to 100 mass%, more preferably 60 to 100 mass%, still more preferably 70 to 100 mass%, and still much more preferably 80 to 100 mass%, based on the total amount (100

mass%) of the metal-based detergent contained in the lubricating oil composition.

[0140] The base number of the metal-based detergent is preferably 0 to 600 mgKOH/g.

[0141] In the lubricating oil composition of one embodiment of the present invention, however, the metal-based detergent is preferably an overbased metal-based detergent having a base number of 100 mgKOH/g or more.

[0142] The base number of the overbased metal-based detergent is 100 mgKOH/g or more, but it is preferably 150 to 500 mgKOH/g, and more preferably 200 to 450 mgKOH/g.

[0143] In the present specification, the "base number" means a base number measured by perchloric acid method in accordance with JIS K2501:2003 "Petroleum products and lubricants - Determination of neutralization number", 7.

[Metal deactivator]

[0144] The lubricating oil composition of one embodiment of the present invention may further contain a metal deactivator. The metal deactivator may be used singly, or may be used in combination of two or more.

[0145] Examples of the metal deactivators used in one embodiment of the present invention include a benzotriazole-based compound, a tolyltriazole-based compound, an imidazole-based compound, and a pyrimidine-based compound.

[Friction modifier]

[0146] The lubricating oil composition of one embodiment of the present invention may further contain a friction modifier. The friction modifier may be used singly, or may be used in combination of two or more.

[0147] Examples of the friction modifiers used in one embodiment of the present invention include molybdenum-based friction modifiers, such as molybdenum dithiocarbamate (MoDTC), molybdenum dithiophosphate (MoDTP), and an amine salt of molybdic acid; ashless 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, each of which has at least one alkyl group or alkenyl group having 6 to 30 carbon atoms; oils and fats, an amine, an amide, and a sulfurized ester.

[Anti-rust agent]

[0148] The lubricating oil composition of one embodiment of the present invention may further contain an anti-rust agent. The anti-rust agent may be used singly, or may be used in combination of two or more.

[0149] Examples of the anti-rust agents used in one embodiment of the present invention include a fatty acid, an alkenyl succinic acid half ester, a fatty acid soap, an alkyl sulfonic acid salt, a polyhydric alcohol fatty acid ester, a fatty acid amine, oxidized paraffin, and an alkyl polyoxyethylene ether.

[Anti-foaming agent]

[0150] The lubricating oil composition of one embodiment of the present invention may further contain an anti-foaming agent. The anti-foaming agent may be used singly, or may be used in combination of two or more.

[0151] Examples of the anti-foaming agents used in one embodiment of the present invention include a silicone oil, a fluorosilicone oil, and a fluoroalkyl ether.

<Method for producing lubricating oil composition>

[0152] The method for producing a lubricating oil composition of one embodiment of the present invention is not particularly limited, but from the viewpoint of productivity, the method preferably has a step of adding the components (B) and (C), and if needed, the component (D) and the aforementioned various additives other than the components (B) to (D), to the component (A).

[0153] Here, preferred compounds and amounts of the components (A) to (D) and various additives are as previously described.

[Properties of lubricating oil composition]

[0154] From the viewpoint of obtaining a lubricating oil composition having been not only more improved in insulation properties but also increased in flash point and thereby having excellent handling properties, the kinematic viscosity of the lubricating oil composition of one embodiment of the present invention at 100°C is preferably 2.1 mm^2/s or more, more preferably 2.2 mm^2/s or more, more preferably 2.4 mm^2/s or more, still more preferably 2.5 mm^2/s or more, still much more preferably 2.7 mm^2/s or more, and particularly preferably 2.8 mm^2/s or more, and from the viewpoint of obtaining a lubricating oil composition having excellent cooling properties, it is preferably less than 5.0 mm^2/s, more

preferably 4.8 mm^2/s or less, more preferably 4.5 mm^2/s or less, more preferably 4.2 mm^2/s or less, still more preferably 4.1 mm^2/s or less, still more preferably 3.9 mm^2/s or less, still much more preferably 3.7 mm^2/s or less, still much more preferably 3.5 mm^2/s or less, and particularly preferably 3.2 mm^2/s or less, or may be 3.0 mm^2/s or less, 2.8 mm^2/s or less, or 2.6 mm^2/s or less.

[0155] The viscosity index of the lubricating oil composition of one embodiment of the present invention is preferably 80 or more, more preferably 90 or more, still more preferably 100 or more, still much more preferably 110 or more, and particularly preferably 117 or more.

[0156] Regarding the lubricating oil composition of one embodiment of the present invention, a load stage that is measured under the conditions described in Examples described later in accordance with ASTM D5182 when scuffing has occurred is preferably 5 or more, more preferably 6 or more, still more preferably 7 or more, and still much more preferably 8 or more.

[0157] Regarding the lubricating oil composition of one embodiment of the present invention, an elution amount of copper for the lubricating oil composition, which is determined when ISOT test in accordance with JIS K2514 has been carried out using a copper fragment as a catalyst at a temperature of 150°C for 72 hours as described in Examples described later, is preferably less than 15 ppm by mass, more preferably 14 ppm by mass or less, still more preferably 13 ppm by mass or less, still much more preferably 12 ppm by mass or less, and particularly preferably 11 ppm by mass or less.

[0158] In the present specification, the elution amount of copper means a value measured in accordance with JPI-5S-38-92.

[0159] Regarding the lubricating oil composition of one embodiment of the present invention, a 100°C kinematic viscosity increase ratio of the lubricating oil composition after an oxidation stability test compared with that before the test, wherein the oxidation stability test is carried out at 160°C for 192 hours in accordance with CEC L-48-A-00 (B) as described in Examples described later, is preferably less than 12%, more preferably 10% or less, more preferably 9% or less, still more preferably 8% or less, still more preferably 7% or less, still much more preferably 6% or less, and particularly preferably 5% or less.

[0160] The 100°C kinematic viscosity increase ratio is a value calculated from the following equation, and the kinematic viscosity is a value measured in accordance with JIS K2283:2000. /s)] - [100°C kinematic

[100°C Kinematic viscosity increase ratio (%)] = ([100°C kinematic viscosity of lubricating oil composition after test (mm^2/s)] - 100°C Kinematic viscosity of lubricating oil composition before test (mm^2/s)]) / [100°C kinematic viscosity of lubricating oil composition before test (mm^2/s)] $\times$ 100

[0161] Regarding the lubricating oil composition of one embodiment of the present invention, a volume resistivity of the lubricating oil composition, which is measured under the conditions described in Examples described later in accordance with JIS C2101, is preferably 1.7×10^7 Ω·m or more, more preferably 1.9×10^7 Ω·m or more, more preferably 2.0×10^7 Ω·m or more, still more preferably 2.2×10^7 Ω·m or more, still more preferably 2.3×10^7 Ω·m or more, still much more preferably 2.5×10^7 Ω·m or more, and particularly preferably 2.7×10^7 Ω·m or more, and is usually 1.0×10^9 Ω·m or less.

[Use application of lubricating oil composition]

[0162] The lubricating oil composition of one preferred embodiment of the present invention can be improved in characteristics of scuffing resistance, copper elution suppressing effect, oxidation stability, insulation properties, etc. in a balanced manner. Particularly, the lubricating oil composition of one preferred embodiment of the present invention can favorably maintain these characteristics even if its viscosity is lowered, and therefore, it is also excellent in cooling properties.

[0163] Taking such characteristics into consideration, the lubricating oil composition of one embodiment of the present invention can be preferably used for lubrication in mechanisms, such as a torque converter, a wet clutch, a gear bearing mechanism, an oil pump and a hydraulic control mechanism, which are incorporated in various apparatuses, such as an engine, a transmission, a speed reducer, a compressor and a hydraulic system. The lubricating oil composition of one embodiment of the present invention is preferably used for lubrication of a speed reducer among these.

[0164] When the aforementioned characteristics of the lubricating oil composition of one embodiment of the present invention are taken into consideration, the present invention can also provide the following [1] and [2] .

[1] A speed reducer using a lubricating oil composition comprising a base oil (A), a thiadiazole-based compound (B) and a boron-modified alkenyl succinimide (C), wherein a content of the component (B) is less than 0.60 mass% based on the total amount of the lubricating oil composition, a content ratio [B/N] by mass of boron atoms to nitrogen

atoms derived from the component (C) is 0.35 or more, and a content of boron atoms derived from the component (C) is 300 ppm by mass or less based on the total amount of the lubricating oil composition.
[2] Use of a lubricating oil composition, in which a lubricating oil composition comprising a base oil (A), a thiadiazole-based compound (B) and a boron-modified alkenyl succinimide (C), wherein a content of the component (B) is less than 0.60 mass% based on the total amount of the lubricating oil composition, a content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) is 0.35 or more, and a content of boron atoms derived from the component (C) is 300 ppm by mass or less based on the total amount of the lubricating oil composition, is applied to lubrication of a speed reducer.

[0165] Preferred embodiments of the lubricating oil composition described in the above [1] and [2] are as previously described.

Examples

[0166] Next, the present invention will be described in much more detail with reference to Examples, but the present invention is in no way limited to these Examples. Measuring methods for various properties are as follows.

(1) Kinematic viscosity, viscosity index

[0167] The kinematic viscosity and viscosity index were measured and calculated in accordance with JIS K2283:2000.

(2) Contents of boron atoms and phosphorus atoms

[0168] The contents were measured in accordance with JPI-5S-38-92.

(3) Content of nitrogen atoms

[0169] The content was measured in accordance with JIS K2609.

(4) Content of sulfur atoms

[0170] The content was measured in accordance with JIS K2541-6:2013.

Examples 1 to 13, Comparative Examples 1 to 7

[0171] A base oil and various additives of types shown in Table 1 were added and mixed in amounts shown in Table 1, thereby preparing each lubricating oil composition. Details of each component used in the preparation of the lubricating oil composition are as follows. In any of the lubricating oil compositions, the content of molybdenum atoms was less than 2 ppm by mass.

<Component (A): base oil>

[0172] "Mineral oil (1)": 60N hydrocracked mineral oil, 100°C kinematic viscosity = 2.2 mm^2/s, viscosity index = 108.
[0173] "Mineral oil (2)": 100N hydrocracked mineral oil, 100°C kinematic viscosity = 4.2 mm^2/s, viscosity index = 122.

<Component (B): thiadiazole-based compound>

[0174] "Thiadiazole (branched chain)": 2,5-bis(1,1-dimethylheptyldithio)-1,3,4-thiadiazole, thiadiazole of the aforementioned general formula (b-1) wherein m = n = 2, and R^1 and R^2 are each a 1,1-dimethylheptyl group; sulfur atom content = 33.3 mass%, nitrogen atom content = 6.4 mass%.

<Component (C): boron-modified alkenyl succinimide>

[0175] "B-Modified polybutenyl bis-succinimide (1)": boron-modified product of polybutenyl bis-succinimide having polybutenyl group, B/N = 1.1.
[0176] "B-Modified polybutenyl bis-succinimide (2)": boron-modified product of polybutenyl bis-succinimide having polybutenyl group, B/N = 0.9.
[0177] "B-Modified polybutenyl bis-succinimide (3)": boron-modified product of polybutenyl bis-succinimide having

polybutenyl group, B/N = 0.5.

[0178] "B-Modified polybutenyl bis-succinimide (4)": boron-modified product of polybutenyl bis-succinimide having polybutenyl group, B/N = 0.2.

<Component (D): phosphorus-based compound>

[0179] "Sulfur-phosphorus-based compound": mixture of sulfur atom-containing phosphorous acid ester of the aforementioned general formula (c-11) wherein a1 = 2, and R^{A11} = n-octyl group and a sulfur atom-containing phosphorous acid ester of the aforementioned general formula (c-12) wherein a2 = a3 = 2, and R^{A21}, R^{A22} = n-octyl group. Phosphorus atom content = 10 mass%, sulfur atom content = 10.7 mass%.

<Ashless dispersant>

[0180] "Non-modified polybutenyl bis-succinimide": polybutenyl bis-succinimide having polybutenyl group, nitrogen atom content: 1.8 mass%.

<Other additives>

[0181] "Additive mixture": mixture of pour point depressant, antioxidant, metal-based detergent, dispersant, metal deactivator, friction modifier and antifoaming agent.

[0182] Regarding the lubricating oil compositions prepared, the kinematic viscosity and viscosity index were measured and calculated, and the following test was carried out. The results of them are set forth in Tables 1 and 2.

(1) FZG scuffing test (A10/16.6R/90)

[0183] A load was stepwise increased based on the regulations using an A10 type gear under the conditions of a sample oil temperature of 90°C, a rotational speed of 2900 rpm and an operating time of about 7.5 minutes in accordance with ASTM D5182, and when scuffing occurred, a stage of the load was determined. It can be said that the larger the value of the stage is, the better the gear scuffing resistance of the lubricating oil composition becomes.

(2) Copper elution test

[0184] Using a copper fragment and an iron fragment as catalysts, ISOT test in accordance with JIS K2514 was carried out at a temperature of 150°C for 72 hours to degrade a sample oil. For the degraded sample oil, an elution amount of copper (unit: ppm by mass) was measured by the method in accordance with JPI-5S-38-92. It can be said that the smaller the value of the elution amount of copper is, the higher the copper elution suppressing effect of the lubricating oil composition becomes.

(3) Oxidation stability test

[0185] An oxidation stability test was carried out under the conditions of 160°C and 192 hours in accordance with CEC L-48-A-00 (B). Thereafter, a 100°C kinematic viscosity of the lubricating oil composition after the test was measured in accordance with JIS K2283:2000, and from the following equation, a 100°C kinematic viscosity increase ratio was calculated.

[100°C Kinematic viscosity increase ratio (%)] = ([100°C kinematic viscosity of lubricating oil composition after test (mm^2/s)] - [100°C kinematic viscosity of lubricating oil composition before test (mm^2/s)]) / [100°C kinematic viscosity of lubricating oil composition before test (mm^2/s)] $\times$ 100

(4) Insulation property test

[0186] A volume resistivity of a sample oil was measured under the test conditions of a measurement temperature of 80°C, an applied voltage of 250 V, and a measurement time of 1 minute in accordance with JIS C2101. It can be said that the larger the value of the volume resistivity is, the better the insulation properties of the lubricating oil composition become.

[Table 1]

[0187]

Table 1

			Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13
Component (A)	Mineral oil (1)	mass%	67.46	67.46	67.46	67.46	71.86	67.46	67.46	67.46	71.86	67.46	67.46	67.46	67.46
	Mineral oil (2)	mass%	27.10	27.54	27.48	27.35	22.20	27.00	27.45	27.30	22.00	27.05	27.05	27.20	27.10
Component (B)	Thiadiazole (branched chain)	mass%	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.10	0.20
Component (C)	B-Modified polybutenyl bis-succinimide (1)	mass%	0.50	0.06	0.13	0.25	1.00								
	B-Modified polybutenyl bis-succinimide (2)	mass%						0.60	0.15	0.30	1.20		0.28	0.60	0.60
	B-Modified polybutenyl bis-succinimide (3)	mass%										0.55			
	B-Modified polybutenyl bis-succinimide (4)	mass%													
Component (D)	Sulfur-phosphorus-based compound	mass%	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Ashless dispersant	Non-modified polybutenyl bis-succinimide	mass%											0.27		

(continued)

			Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13
Other additives	Additive mixture	mass%	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34
Total		mass%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Content of boron atoms (B) derived from component (C)		ppm by mass	95	12	24	48	190	78	20	39	156	46	36	78	78
Content of nitrogen atoms (N) derived from component (C)		ppm by mass	88	11	22	44	176	87	22	44	174	86	41	87	87
Ratio of BIN derived from component (C)		(mass ratio)	1.1	1.1	1.1	1.1	1.1	0.9	0.9	0.9	0.9	0.5	0.9	0.9	0.9
Various properties	40°C kinematic viscosity	mm^2/s	11.5	11.2	11.3	11.4	11.2	11.5	11.4	11.5	11.4	11.5	11.5	11.5	11.5
	100°C kinematic viscosity	mm^2/s	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Viscosity index	-	117	126	123	120	126	117	120	117	120	117	117	117	117
Various tests	(1) FZG scuffing test, Stage	-	8	8	8	8	8	8	8	8	8	8	8	6	7
	(2) Copper elution test, Elution amount of copper	ppm by mass	10	10	9	10	7	11	9	10	9	12	13	7	9
	(3) Oxidation stability test, Kinematic viscosity increase ratio	%	5	8	6	5	4	5	6	5	4	5	6	4	5
	(4) Insulation property test, Volume resistivity	$\times 10^7 \Omega$ m	2.3	3.2	3.0	2.9	2.0	2.8	3.0	2.8	2.1	2.8	2.8	3.3	3.0

[Table 2]

[0188]

Table 2

			Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Comp. Ex. 6	Comp. Ex. 7
Component (A)	Mineral oil (1)	mass%	67.46	67.46	67.46	77.66	77.66	67.46	67.46
	Mineral oil (2)	mass%	27.60	27.05	27.05	15.40	15.00	26.70	26.40
Component (B)	Thiadiazole (branched chain)	mass%	0.30	0.30	0.30	0.30	0.30	0.60	0.90
Component (C)	B-Modified polybutenyl bis-succinimide (1)	mass%				2.00			
	B-Modified polybutenyl bis-succinimide (2)	mass%					2.40	0.60	0.60
	B-Modified polybutenyl bis-succinimide (3)	mass%							
	B-Modified polybutenyl bis-succinimide (4)	mass%			0.55				
Component (D)	Sulfur-phosphorus-based compound	mass%	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Ashless dispersant	Non-modified polybutenyl bis-succinimide	mass%		0.55					
Other additives	Additive mixture	mass%	4.34	4.34	4.34	4.34	4.34	4.34	4.34
Total		mass%	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Content of boron atoms (B) derived from component (C)		ppm by mass	-	-	19	380	312	78	78
Content of nitrogen atoms (N) derived from component (C)		ppm by mass	-	-	87	352	348	87	87
Ratio of BIN derived from component (C)		(mass ratio)	-	-	0.2	1.1	0.9	0.9	0.9

(continued)

			Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Comp. Ex. 6	Comp. Ex. 7
Various properties	40°C kinematic viscosity	mm^2/s	11.4	11.6	11.4	10.9	11.3	11.6	11.6
	100°C kinematic viscosity	mm^2/s	3.0	3.0	3.0	2.9	3.0	3.0	3.0
	Viscosity index	-	120	114	120	117	123	114	114
Various tests	(1) FZG scuffing test, Stage	-	8	8	8	4	4	8	7
	(2) Copper elution test, Elution amount of copper	ppm by mass	9	18	15	7	8	27	37
	(3) Oxidation stability test, Kinematic viscosity increase ratio	%	12	7	8	4	4	15	26
	(4) Insulation property test, Volume resistivity	$\times 10^7 \Omega$ m	3.0	2.4	2.6	1.5	1.6	2.6	2.2

[0189] From Table 1, the results for the lubricating oil compositions of Examples 1 to 13 were superior in all characteristics of scuffing resistance, copper elution suppressing effect, oxidation stability and insulation properties in a balanced manner.

[0190] In contrast, from Table 2, the result for the lubricating oil composition of Comparative Example 1 was inferior in oxidation stability, and the results for the lubricating oil compositions of Comparative Examples 2 to 3, and 6 to 7 were inferior in copper elution suppressing effect. The results for the lubricating oil compositions of Comparative Examples 4 to 5 were inferior not only in scuffing resistance but also in insulation properties.

Claims

1. A lubricating oil composition comprising a base oil (A), a thiadiazole-based compound (B) and a boron-modified alkenyl succinimide (C), wherein

   a content of the component (B) is less than 0.60 mass% based on the total amount of the lubricating oil composition,
   a content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) is 0.35 or more, and
   a content of boron atoms derived from the component (C) is 300 ppm by mass or less based on the total amount of the lubricating oil composition.

2. The lubricating oil composition according to claim 1, wherein a content of nitrogen atoms derived from the component (C) is 320 ppm by mass or less based on the total amount of the lubricating oil composition.

3. The lubricating oil composition according to claim 1 or 2, wherein a content of nitrogen atoms derived from the component (C) is 5.0 to 320 ppm by mass based on the total amount of the lubricating oil composition.

4. The lubricating oil composition according to any one of claims 1 to 3, wherein the content ratio [B/N] by mass of boron atoms to nitrogen atoms derived from the component (C) is 0.35 to 2.0.

5. The lubricating oil composition according to any one of claims 1 to 4, wherein the content of boron atoms derived from the component (C) is 3.0 to 300 ppm by mass based on the total amount of the lubricating oil composition.

6. The lubricating oil composition according to any one of claims 1 to 5, wherein the component (C) comprises a boron-modified alkenyl bis-succinimide (C1).

7. The lubricating oil composition according to any one of claims 1 to 6, wherein the component (B) comprises a thiadiazole-based compound (B1) having a branched chain alkyl group.

8. The lubricating oil composition according to any one of claims 1 to 7, wherein a content of a sulfurized olefin is less than 0.20 mass% based on the total amount of the lubricating oil composition.

9. The lubricating oil composition according to any one of claims 1 to 8, wherein a kinematic viscosity of the lubricating oil composition at 100°C is 2.1 mm^2/s or more and less than 5.0 mm^2/s.

10. The lubricating oil composition according to any one of claims 1 to 9, further comprising one or more phosphorus-based compounds (D) selected from a phosphoric acid ester and a phosphorous acid ester.

11. The lubricating oil composition according to claim 10, wherein the component (D) comprises one or more sulfur-phosphorus-based compounds (D1) selected from a sulfur atom-containing phosphoric acid ester and a sulfur atom-containing phosphorous acid ester.

12. The lubricating oil composition according to any one of claims 1 to 11, being used for lubrication of a speed reducer.

13. A speed reducer to which the lubricating oil composition according to any one of claims 1 to 12 has been applied.

14. Use of a lubricating oil composition, wherein the lubricating oil composition according to any one of claims 1 to 12 is applied to lubrication of a speed reducer.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/025869

A. CLASSIFICATION OF SUBJECT MATTER

C10M 141/08(2006.01)i; *C10N 30/00*(2006.01)n; *C10N 30/06*(2006.01)n; *C10N 30/10*(2006.01)n; *C10N 30/14*(2006.01)n; *C10N 40/04*(2006.01)n; *C10N 40/08*(2006.01)n; *C10N 40/25*(2006.01)n; *C10N 40/30*(2006.01)n; *C10M 133/16*(2006.01)n; *C10M 133/56*(2006.01)n; *C10M 135/36*(2006.01)n; *C10M 137/02*(2006.01)n; *C10M 137/04*(2006.01)n; *C10M 137/10*(2006.01)n; *C10M 139/00*(2006.01)n

FI: C10M141/08; C10M133/16; C10M133/56; C10M135/36; C10M137/02; C10M137/04; C10M137/10 Z; C10M139/00 A; C10N30:00 Z; C10N30:06; C10N30:10; C10N30:14; C10N40:04; C10N40:08; C10N40:25; C10N40:30

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)

C10M1/00-177/00

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.
X	JP 2014-159496 A (JX NIPPON OIL & ENERGY CORPORATION) 04 September 2014 (2014-09-04) paragraphs [0041], [0056], [0070], [0088], [0093]	1-14
A	WO 2019/177125 A1 (IDEMITSU KOSAN CO., LTD.) 19 September 2019 (2019-09-19) entire text	1-14
A	JP 2019-38961 A (JX NIPPON OIL & ENERGY CORP) 14 March 2019 (2019-03-14) entire text	1-14
A	JP 2020-90558 A (EMG LUBRICANTS GK) 11 June 2020 (2020-06-11) entire text	1-14

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
18 August 2022	**06 September 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/025869

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2014-159496 A	04 September 2014	US 2015/0376544 A1 paragraphs [0065], [0085], [0102], [0122]-[0123], table 1 EP 2960321 A1 CN 105051171 A WO 2014/129032 A1	
WO 2019/177125 A1	19 September 2019	US 2021/0047581 A1 entire text EP 3766948 A1	
JP 2019-38961 A	14 March 2019	(Family: none)	
JP 2020-90558 A	11 June 2020	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2012193255 A **[0004]**