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(54) **LUBRICANT COMPOSITION**

(57) An object of the present invention is to provide a lubricating oil composition capable of satisfactorily exhibiting sludge prevention properties and wear resistance evaluated by scoring resistance and seizure resistance over a long period of time. The object is achieved by providing a lubricating oil composition containing: a base oil (A); a hindered phenol-based antioxidant (B); one or more imide compounds (C) selected from the group consisting of a monoimide compound (C1) and a

bisimide compound (C2); and an extreme pressure agent (D), in which the hindered phenol-based antioxidant (B) is 2,6-di-tert-butylphenol, the monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound, and the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound.

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Description

Technical Field

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

Background Art

10 **[0002]** Hydraulic equipment mounted on a construction machine such as a hydraulic excavator, a crane, a wheel loader, and a bulldozer is required to operate under a high pressure, a high temperature, a high speed, and a high load.

[0003] Therefore, a lubricating oil composition used as a power transmission medium in the hydraulic equipment for the construction machine is required to have wear resistance and oxidation stability so as not to impair performance of the hydraulic equipment even when used for a long period of time under a high pressure, a high temperature, a high speed, and a high load.

15 **[0004]** In particular, a lubricating oil composition used in hydraulic equipment having an operating pressure of 30 MPa or more is likely to have deterioration in oxidation stability and lubricating performance at an early stage, and is likely to cause adverse effects such as sludge generation and operational failures.

20 **[0005]** For example, PTL 1 proposes, as a hydraulic oil composition used in hydraulic equipment for a construction machine having an operating pressure of 30 MPa or more, a hydraulic oil composition containing an amine-based antioxidant, a phenol-based antioxidant, and a phosphate ester each in a predetermined ratio in a polyolefin having a predetermined kinematic viscosity.

[0006] PTL 1 discloses that the hydraulic oil composition is excellent in oxidation stability and lubricating performance under a high pressure, effectively prevents early deterioration, sludge generation, and the like under a high pressure, and can be used for a long period of time.

Citation List

Patent Literature

30 **[0007]** PTL 1: JP H09-111277 A

Summary of Invention

Technical Problem

35 **[0008]** In recent years, hydraulic equipment is aimed to achieve higher performance such as higher pressure, smaller size, higher speed, and higher accuracy. Therefore, performance required for a lubricating oil composition used in the hydraulic equipment is more stringent. Therefore, it is desired to further improve the performance of the lubricating oil composition used in the hydraulic equipment.

40 **[0009]** From this viewpoint, in recent years, an "FZG scoring test" that defines lubricity such as wear resistance has been adopted in ISO standards for hydraulic oil (ISO-14635).

[0010] In addition, when a large amount of sludge is generated in the hydraulic equipment, valve lock and wear of a hydraulic pump are caused. In order to further improve the performance of the lubricating oil composition used in the hydraulic equipment, it is required to reduce an amount of sludge generated over a long period of time to an extremely small amount.

45 **[0011]** Further, due to high performance of the hydraulic equipment, seizure or the like may be more likely to occur. In order to further improve the performance of the lubricating oil composition used in the hydraulic equipment, the lubricating oil composition is also required to exhibit excellent seizure resistance over a long period of time.

50 **[0012]** That is, in view of the recent circumstances in which the hydraulic equipment is aimed to achieve higher performance, the lubricating oil composition used for the hydraulic equipment is required to have excellent performance of reducing an amount of sludge generated to an extremely small amount over a long period of time (hereinafter, also referred to as "sludge prevention properties") and to be capable of satisfactorily exhibiting wear resistance evaluated by scoring resistance, seizure resistance, and the like over a long period of time.

[0013] However, in PTL 1, such studies are not sufficiently conducted.

55 **[0014]** An object of the present invention is to provide a lubricating oil composition capable of satisfactorily exhibiting sludge prevention properties and wear resistance evaluated by scoring resistance and seizure resistance over a long period of time.

Solution to Problem

[0015] As a result of intensive studies, the present inventors have found that a lubricating oil composition containing a specific phenol-based antioxidant and containing two specific imide compounds can solve the above problems.

[0016] That is, the present invention relates to the following [1],

[1] A lubricating oil composition containing: a base oil (A); a hindered phenol-based antioxidant (B); one or more imide compounds (C) selected from the group consisting of a monoimide compound (C1) and a bisimide compound (C2); and an extreme pressure agent (D), in which the hindered phenol-based antioxidant (B) is 2,6-di-tert-butylphenol, the monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound, and the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound.

Advantageous Effects of Invention

[0017] According to the present invention, it is possible to provide a lubricating oil composition capable of satisfactorily exhibiting sludge prevention properties and wear resistance evaluated by scoring resistance and seizure resistance over a long period of time.

Description of Embodiments

[0018] In the present description, a lower limit value and an upper limit value described in a stepwise manner in a preferable numerical range (for example, a range of content or the like) can be independently combined. For example, regarding description of "preferably 10 to 90, and more preferably 30 to 60", the "preferable lower limit value (10)" and the "more preferable upper limit value (60)" can be combined to be "10 to 60".

[0019] In addition, in the present description, numerical values in Examples are numerical values that can each be used as an upper limit value or a lower limit value.

[0020] In addition, in the present description, a numerical range described as "AA to BB" means "AA or more and BB or less" unless otherwise specified.

[Embodiment of Lubricating Oil Composition of Present Invention]

[0021] A lubricating oil composition of the present invention contains: a base oil (A); a hindered phenol-based antioxidant (B); one or more imide compounds (C) selected from the group consisting of a monoimide compound (C1) and a bisimide compound (C2); and an extreme pressure agent (D), in which the hindered phenol-based antioxidant (B) is 2,6-di-tert-butylphenol, the monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound, and the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound.

[0022] The present inventors have conducted intensive studies to provide a lubricating oil composition capable of satisfactorily exhibiting sludge prevention properties and wear resistance evaluated by scoring resistance and seizure resistance over a long period of time.

[0023] First, from the viewpoint of sludge prevention properties, it is conceivable to use a combination of a phenol-based antioxidant and an imide compound. However, it is conceivable that the imide compound is capable of improving the sludge prevention properties, and on the other hand, decreases performance of the extreme pressure agent, thereby causing a decrease in wear resistance of the lubricating oil composition. In addition, it is conceivable that the extreme pressure agent imparts wear resistance to the lubricating oil composition, and on the other hand, causes sludge generation.

[0024] Considering these points comprehensively, the present inventors have considered that it is important to solve at least the following two points in order to achieve the object of the present invention.

(1) To prevent the decrease in performance of the extreme pressure agent caused when using the extreme pressure agent in combination with the imide compound.

(2) To prevent the sludge generation caused by addition of the extreme pressure agent.

[0025] From this viewpoint, the present inventors have conducted further intensive studies.

[0026] As a result, it has been found that, instead of 2,6-di-tert-butyl-p-cresol (hereinafter, also referred to as "DBPC"), which is a phenol-based antioxidant used in a lubricating oil composition used in a hydraulic equipment or the like in the

related art, a lubricating oil composition containing 2,6-di-tert-butylphenol (hereinafter, also referred to as "DTBP") in which a methyl group in a cresol skeleton of DBPC is changed to a hydrogen atom has a function of preventing the sludge generation caused by the addition of the extreme pressure agent and greatly improving sludge prevention properties.

[0027] In addition, the present inventors have found that, by using a monoimide compound and a bisimide compound in combination as the imide compound, it is possible to prevent the decrease in performance of the extreme pressure agent caused when using the extreme pressure agent in combination with the imide compound, and thus it is possible to sufficiently exhibit the performance of the extreme pressure agent.

[0028] Based on these results, the present inventors have made further intensive studies and completed the present invention.

[0029] Although a reason why the above effects of the present invention are exhibited is not clear, for example, the following is presumed.

[0030] That is, it is presumed that DTBP in which the methyl group in the cresol skeleton of DBPC is changed to a hydrogen atom is multimerized (for example, dimerized) in the lubricating oil composition, and is thus easier to stay in the lubricating oil composition as compared with DBPC and can sufficiently exhibit performance as an antioxidant, the monoimide compound improves dispersibility of the extreme pressure agent, and the bisimide compound tends to form a reaction field of the extreme pressure agent on a metal surface, so that effects of the present invention are exhibited.

[0031] In the following description, the "base oil (A)", the "hindered phenol-based antioxidant (B)", the "imide compound (C)", and the "extreme pressure agent (D)" are also referred to as the "component (A)", the "component (B)", the "component (C)", and the "component (D)", respectively.

[0032] The lubricating oil composition in one embodiment of the present invention can contain only the "component (A)", the "component (B)", the "component (C)", and the "component (D)", and can also contain components other than the "component (A)", the "component (B)", the "component (C)", and the "component (D)" as long as the effects of the present invention are not impaired.

[0033] In the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, a total content of the "component (A)", the "component (B)", the "component (C)", and the "component (D)" is preferably 70.0% by mass or more, more preferably 75.0% by mass or more, still more preferably 80.0% by mass or more, and yet still more preferably 85.0% by mass or more, based on a total amount of the lubricating oil composition.

[0034] An upper limit value of the total content of the component (A), the component (B), the component (C), and the component (D) can be adjusted in view of a balance with components other than the component (A), the component (B), the component (C), and the component (D), and is preferably 99.0% by mass or less, more preferably 98.0% by mass or less, and still more preferably 97.0% by mass or less, based on the total amount of the lubricating oil composition.

[0035] Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the total content is preferably 70.0% by mass to 99.0% by mass, more preferably 75.0% by mass to 98.0% by mass, still more preferably 80.0% by mass to 98.0% by mass, and yet still more preferably 85.0% by mass to 97.0% by mass.

[0036] Hereinafter, the base oil (A), the hindered phenol-based antioxidant (B), the imide compound (C), the extreme pressure agent (D), and other components will be described in detail.

«Base Oil (A)»

[0037] The lubricating oil composition of the present invention contains the base oil (A).

[0038] As the base oil (A), one or more selected from a mineral oil and a synthetic oil used in the related art as base oils for lubricating oils can be used without particular limitation.

[0039] Examples of the mineral oil include: an atmospheric residual oil obtained by atmospheric distillation of a crude oil, such as a paraffinic crude oil, an intermediate base crude oil, or a naphthenic crude oil; a distillate oil obtained by vacuum distillation of the atmospheric residual oil; and a mineral oil obtained by subjecting the distillate oil to one or more refining treatments such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, and hydrorefining.

[0040] Examples of the synthetic oil include: poly- α -olefins such as α -olefin homopolymers and α -olefin copolymers (for example, α -olefin copolymers each having 8 to 14 carbon atoms, such as ethylene- α -olefin copolymers); isoparaffins; esters such as polyol esters and dibasic esters; various ethers such as polyphenyl ether; polyalkylene glycols; alkylbenzenes; alkylnaphthalenes; and gas-to-liquid (GTL) base oils obtained by isomerizing a wax (GTL wax) produced from a natural gas by a Fischer-Tropsch method or the like.

[0041] As the base oil (A), a mineral oil can be used alone or a plurality of mineral oils can be used in combination, or a synthetic oil can be used alone or a plurality of synthetic oils can be used in combination. In addition, one or more mineral oils and one or more synthetic oils can be used in combination.

[0042] From the viewpoint of further improving the oxidation stability of the lubricating oil composition, the base oil (A)

is preferably one or more selected from base oils classified into Groups II, III, and IV in the base oil category of the American Petroleum Institute (API), and more preferably one or more selected from the base oils classified into Groups II and III.

[0043] A kinematic viscosity at 40°C of the base oil (A) (hereinafter also referred to as the "40°C kinematic viscosity") is preferably 10 mm²/s to 150 mm²/s, more preferably 15 mm²/s to 100 mm²/s, and still more preferably 20 mm²/s to 80 mm²/s.

[0044] When the kinematic viscosity at 40°C of the base oil (A) is 10 mm²/s or more, a lubricating oil composition having a high flash point and excellent lubricating performance is easily obtained.

[0045] In addition, when the kinematic viscosity at 40°C of the base oil (A) is 150 mm²/s or less, viscosity resistance at a low temperature is not excessively large, and thus an operation of a machine is easily improved.

[0046] A viscosity index of the base oil (A) is preferably 80 or more, more preferably 90 or more, still more preferably 100 or more, and yet still more preferably 110 or more. When the viscosity index of the base oil (A) is in the above range, a viscosity change caused by a temperature change can be reduced, an oil film can be easily formed under a high temperature, and thus wear resistance is easily improved.

[0047] When the base oil (A) is a mixed base oil containing two or more types of base oils, the 40°C kinematic viscosity and the viscosity index of the mixed base oil are preferably within the above ranges.

[0048] In the present description, the kinematic viscosity at 40°C and the viscosity index refer to values measured or calculated according to JIS K 2283:2000.

[0049] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, a content of the base oil (A) is preferably 80.0% by mass or more, more preferably 83.0% by mass or more, and still more preferably 85.0% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 98.0% by mass or less, more preferably 97.0% by mass or less, and still more preferably 96.0% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 80.0% by mass to 98.0% by mass, more preferably 83.0% by mass to 97.0% by mass, and still more preferably 85.0% by mass to 96.0% by mass.

<<Hindered Phenol-based Antioxidant (B)>>

[0050] The lubricating oil composition of the present invention contains the hindered phenol-based antioxidant (B), and the hindered phenol-based antioxidant (B) is 2,6-di-tert-butylphenol.

[0051] In a case where the lubricating oil composition does not contain 2,6-di-tert-butylphenol, excellent sludge prevention properties cannot be obtained.

[0052] According to the studies conducted by the present inventors, when 2,6-di-tert-butyl-p-cresol is used in which a hydrogen atom at a 4 position (para position) of a phenyl group in 2,6-di-tert-butylphenol is substituted with a methyl group, excellent sludge prevention properties cannot be obtained. That is, it is presumed that the effects of the present invention are exhibited due to a slight structure difference in the phenol-based antioxidant (that is, presence or absence of the methyl group).

(Content of Hindered Phenol-based Antioxidant (B))

[0053] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of obtaining a lubricating oil composition having more excellent sludge prevention properties, a content of the hindered phenol-based antioxidant (B) is preferably 0.40% by mass or more, more preferably 0.50% by mass or more, still more preferably 0.60% by mass or more, yet still more preferably 0.65% by mass or more, and even still more preferably 0.70% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 2.0% by mass or less, more preferably 1.5% by mass or less, still more preferably 1.2% by mass or less, yet still more preferably 1.0% by mass or less, and even still more preferably 0.90% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.40% by mass to 2.0% by mass, more preferably 0.50% by mass to 1.5% by mass, still more preferably 0.60% by mass to 1.2% by mass, yet still more preferably 0.65% by mass to 1.0% by mass, and even still more preferably 0.70% by mass to 0.90% by mass.

<<Imide Compound (C)>>

[0054] The lubricating oil composition of the present invention contains one or more imide compounds (C) selected from the group consisting of the monoimide compound (C1) and the bisimide compound (C2). In a case where the lubricating oil composition does not contain the imide compound (C), excellent sludge prevention properties cannot be

obtained. On the other hand, as described above, when the lubricating oil composition contains the imide compound (C), there is a problem that the performance of the extreme pressure agent (D) is deteriorated. In the present invention, in view of such a problem, one or more imide compounds (C) selected from the group consisting of the monoimide compound (C1) and the bisimide compound (C2) are used as the imide compound (C).

[0055] Accordingly, the performance of the extreme pressure agent (D) is sufficiently exhibited without being deteriorated, and thus a lubricating oil composition having excellent wear resistance is obtained.

[0056] The monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound.

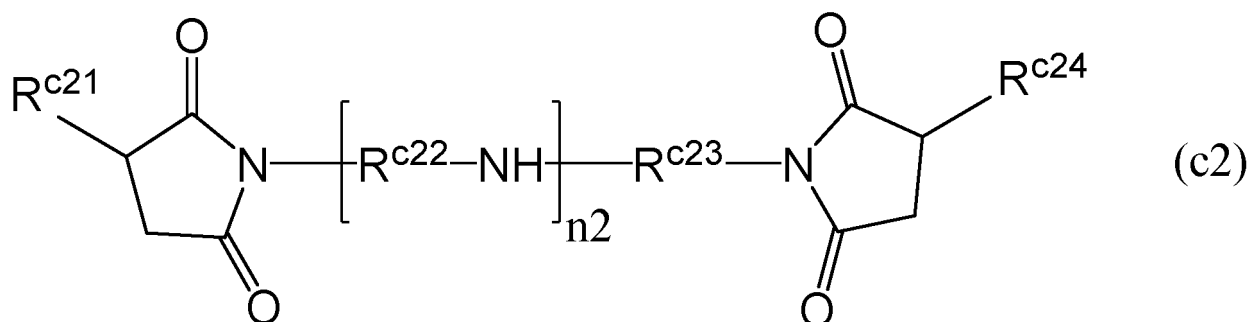
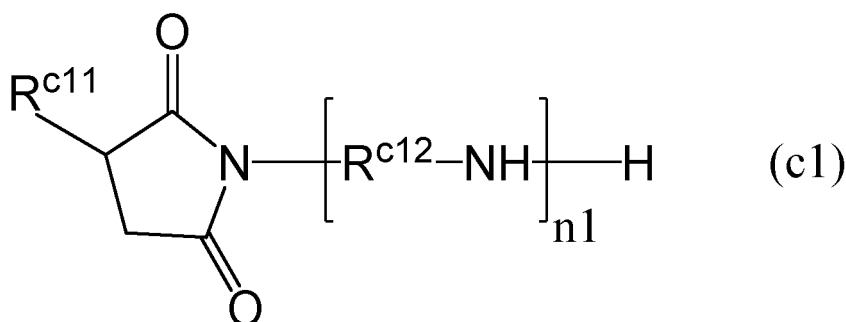
[0057] In addition, the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound.

[0058] In the following description, the "monoimide compound (C1)" is also simply referred to as the "component (C1)". In addition, the "bisimide compound (C2)" is also simply referred to as the "component (C2)".

[0059] Hereinafter, the monoimide compound (C1) and the bisimide compound (C2) will be described in detail.

(Monoimide Compound (C1) and Bisimide Compound (C2))

[0060] The monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound. As the alkenyl succinic monoimide compound and the alkyl succinic monoimide compound, for example, a compound represented by the following general formula (c1) is preferable. In addition, the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound. As the alkenyl succinic bisimide compound and the alkyl succinic bisimide compound, for example, a compound represented by the following general formula (c2) is preferable.



[0061] In the general formula (c1), $\text{R}^{\text{c}11}$ is an alkenyl group or an alkyl group, $\text{R}^{\text{c}12}$ is an alkylene group having 1 to 6 carbon atoms, and $n1$ is an integer of 1 to 20. In addition, when $n1$ is 2 or more, a plurality of $\text{R}^{\text{c}12}$'s can be the same as or different from one another.

[0062] In the general formula (c2), $\text{R}^{\text{c}21}$ and $\text{R}^{\text{c}24}$ are each independently an alkenyl group or an alkyl group, $\text{R}^{\text{c}22}$ and $\text{R}^{\text{c}23}$ are each independently an alkylene group having 1 to 6 carbon atoms, and $n2$ is an integer of 0 to 20. In addition, when $n2$ is 2 or more, a plurality of $\text{R}^{\text{c}22}$'s can be the same as or different from one another.

[0063] From the viewpoint of improving solubility in the base oil (A) and making it easier to exhibit the effects of the present invention, the alkenyl group or alkyl group that can be selected as $\text{R}^{\text{c}11}$, $\text{R}^{\text{c}21}$, and $\text{R}^{\text{c}24}$ has a mass average molecular weight (M_w) of preferably 500 or more, more preferably 1,000 or more, still more preferably 2,000 or more, yet still more preferably 3,000 or more, and even still more preferably 4,000 or more. In addition, the mass average

molecular weight is preferably 10,000 or less, more preferably 90,000 or less, and still more preferably 8,000 or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the mass average molecular weight is preferably 500 to 10,000, more preferably 1,000 to 10,000, still more preferably 2,000 to 10,000, yet still more preferably 3,000 to 9,000, and even still more preferably 4,000 to 8,000.

[0064] Examples of the alkenyl group that can be selected as R^{c11} , R^{c21} , and R^{c24} include a polybutenyl group, a polyisobutenyl group, and an ethylene-propylene copolymer, and examples of the alkyl group that can be selected as R^{c11} , R^{c21} , and R^{c24} include those hydrogenated with the above groups. As a polybutenyl group, a mixture of 1-butene and isobutene or one obtained by polymerizing high-purity isobutene is preferably used. Among these, the alkenyl group is preferably a polybutenyl group or an isobutenyl group, and examples of the alkyl group include those hydrogenated with a polybutenyl group or an isobutenyl group.

[0065] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, the group that can be selected as R^{c11} , R^{c21} , and R^{c24} is preferably an alkenyl group, and more preferably a polybutenyl group among alkenyl groups.

[0066] From the viewpoint of improving the solubility in the base oil (A) and making it easier to exhibit the effects of the present invention, an alkylene group having 1 to 6 carbon atoms, which can be selected as R^{c12} , R^{c22} , and R^{c23} , is preferably a methylene group, various ethylene groups such as a 1,1-ethylene group and a 1,2-ethylene group, various propylene groups such as 1,3-propylene, 1,2-propylene, and 2,2-propylene, various butylene groups, various pentylene groups, and various hexylene groups.

[0067] In addition, from the same viewpoint, the number of carbon atoms in the alkylene group that can be selected as R^{c12} , R^{c22} , and R^{c23} is preferably 2 to 5, more preferably 2 to 4, and still more preferably 2 or 3.

[0068] From the viewpoint of improving the solubility in the base oil (A) and making it easier to exhibit the effects of the present invention, $n1$ in the general formula (c1) is preferably 2 to 15, more preferably 3 to 10, still more preferably 3 to 5, and yet still more preferably 3 or 4.

[0069] From the viewpoint of improving solubility of the component (C2) represented by the general formula (c2) in the base oil and making it easier to exhibit the effects of the present invention, $n2$ in the general formula (c2) is preferably 1 to 15, more preferably 2 to 10, still more preferably 2 to 5, and yet still more preferably 3 or 4.

[0070] The alkenyl succinic monoimide, the alkyl succinic monoimide, the alkenyl succinic bisimide, or the alkyl succinic bisimide can be generally prepared by reacting, with a polyamine, an alkenyl succinic anhydride obtained by reacting a polyolefin with a maleic anhydride, or an alkyl succinic anhydride obtained by hydrogenating the alkenyl succinic anhydride. The monoimide form and the bisimide form can each be prepared by changing a reaction ratio of the alkenyl succinic anhydride or the alkyl succinic anhydride to the polyamine.

[0071] As an olefin monomer forming the polyolefin, one or more selected from α -olefins having 2 to 8 carbon atoms can be mixed and used, and a mixture of isobutene and 1-butene can be preferably used.

[0072] Meanwhile, examples of the polyamine include diamines such as ethylenediamine, propylenediamine, butylenediamine, and pentylenediamine, and polyalkylene polyamines such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, di(methylethylene)triamine, dibutylenetriamine, tributylene tetramine, and pentapentylenehexamine.

(Total Content of Monoimide Compound (C1) and Bisimide Compound (C2))

[0073] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, a total content of the monoimide compound (C1) and the bisimide compound (C2) is preferably 0.10% by mass or more, more preferably 0.13% by mass or more, still more preferably 0.15% by mass or more, and yet still more preferably 0.17% by mass or more, based on the total amount of the lubricating oil composition. In addition, the total content is preferably 0.50% by mass or less, more preferably 0.40% by mass or less, still more preferably 0.35% by mass or less, and yet still more preferably 0.30% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the total content is preferably 0.10% by mass to 0.50% by mass, more preferably 0.13% by mass to 0.40% by mass, still more preferably 0.15% by mass to 0.35% by mass, and yet still more preferably 0.17% by mass to 0.30% by mass.

(Content Ratio [(C1)/(C2)] of Monoimide Compound (C1) to Bisimide Compound (C2))

[0074] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, a content ratio [(C1)/(C2)] of the monoimide compound (C1) to the bisimide compound (C2) is preferably more than 0, more preferably 1/3 or more, and still more preferably 2/3 or more in terms of a mass ratio. In addition, the content ratio is preferably 2/1 or less, and more preferably 3/2 or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content ratio is preferably more than 0 and 2/1 or less, more preferably 1/3 to 3/2, and still more preferably 2/3 to 3/2.

<<Extreme Pressure Agent (D)>>

[0075] The lubricating oil composition of the present invention contains the extreme pressure agent (D).

[0076] When the lubricating oil composition does not contain the extreme pressure agent (D), a lubricating oil composition having excellent wear resistance cannot be obtained.

[0077] Here, in the lubricating oil composition according to the embodiment of the present invention, the extreme pressure agent (D) preferably contains one or more selected from the group consisting of a phosphorus-based extreme pressure agent (D1) and a sulfur-phosphorus-based extreme pressure agent (D2).

[0078] In the following description, the "phosphorus-based extreme pressure agent (D1)" is also simply referred to as the "component (D1)". In addition, the "sulfur-phosphorus-based extreme pressure agent (D2)" is also simply referred to as the "component (D2)".

[0079] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of obtaining a lubricating oil composition having excellent wear resistance, a content of one or more components selected from the group consisting of the "component (D1)" and the "component (D2)" is preferably 80% by mass to 100% by mass, more preferably 85% by mass to 100% by mass, still more preferably 90% by mass to 100% by mass, and yet still more preferably 95% by mass to 100% by mass based on a total amount of the extreme pressure agent (D).

[0080] Hereinafter, the "phosphorus-based extreme pressure agent (D1)" and the "sulfur-phosphorus-based extreme pressure agent (D2)" will be described in detail.

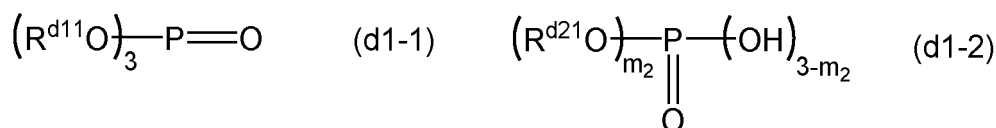
(Phosphorus-based Extreme Pressure Agent (D1))

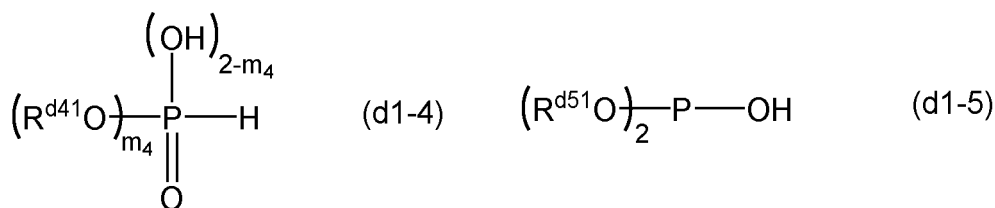
[0081] The lubricating oil composition according to the embodiment of the present invention preferably contains the phosphorus-based extreme pressure agent (D1). When the lubricating oil composition contains the phosphorus-based extreme pressure agent (D1), excellent wear resistance is easily imparted to the lubricating oil composition. In addition, by using the phosphorus-based extreme pressure agent (D1) in combination with the component (B), the component (C1), and the component (C2), a decrease in sludge prevention properties caused by addition of the phosphorus-based extreme pressure agent (D1) is alleviated, and thus performance of the phosphorus-based extreme pressure agent (D1) is exhibited well.

[0082] In the present description, the phosphorus-based extreme pressure agent (D1) refers to an extreme pressure agent containing a phosphorus atom and having extreme pressure performance. An extreme pressure agent containing a sulfur atom and a phosphorus atom is classified into the sulfur-phosphorus-based extreme pressure agent (D2) instead of being classified into the phosphorus-based extreme pressure agent (D1).

[0083] Preferred examples of the phosphorus-based extreme pressure agent (D1) include phosphate ester compounds such as a phosphate ester, an acidic phosphate ester, a phosphite ester, and a hydrogen phosphite ester, and an amine salt of the phosphate ester compounds. More specifically, preferred examples of the phosphate ester, the acidic phosphate ester, the phosphite ester, and the hydrogen phosphite ester respectively include a phosphate ester represented by the following general formula (d1-1), an acidic phosphate ester represented by the following general formula (d1-2), a phosphite ester represented by the following general formula (d1-3), and a hydrogen phosphite ester represented by the following general formulas (d1-4) and (d1-5).

[0084] The phosphorus-based extreme pressure agent (D1) can be used alone or two or more types of phosphorus-based extreme pressure agents (D1) can be used in combination.





[0085] In the general formulas (d1-1) to (d1-5), R^{d11} , R^{d21} , R^{d31} , R^{d41} , and R^{d51} each independently represent a hydrocarbon group having 1 to 30 carbon atoms. From the viewpoint of obtaining more excellent wear resistance, preferred examples of the hydrocarbon group include an alkyl group, an alkenyl group, an aryl group, and an arylalkyl group.

[0086] In a case where R^{d11} , R^{d21} , R^{d31} , R^{d41} , and R^{d51} are each an alkyl group, from the viewpoint of obtaining more excellent wear resistance and further considering availability and the like, the number of carbon atoms is preferably 2 to 20, and more preferably 2 to 10. The alkyl group can be linear, branched, or cyclic, and is preferably linear or branched in view of availability.

[0087] In a case where R^{d11} , R^{d21} , R^{d31} , R^{d41} , and R^{d51} are each an alkenyl group, from the viewpoint of obtaining more excellent wear resistance and further considering availability and the like, the number of carbon atoms is preferably 2 to 20, and more preferably 2 to 10. The alkenyl group can be linear, branched, or cyclic, and is preferably linear or branched.

[0088] In a case where R^{d11} , R^{d21} , R^{d31} , R^{d41} , and R^{d51} are each an aryl group, from the viewpoint of obtaining more excellent seizure resistance and wear resistance, and further considering availability and the like, the number of carbon atoms is preferably 6 to 20, and more preferably 6 to 15.

[0089] In a case where R^{d11} , R^{d21} , R^{d31} , R^{d41} , and R^{d51} are each an arylalkyl group, from the viewpoint of obtaining more excellent seizure resistance and wear resistance, and further considering availability and the like, the number of carbon atoms is preferably 6 to 20, and more preferably 6 to 15.

[0090] A plurality of R^{d11} 's, R^{d31} 's, and R^{d51} 's can be the same as or different from one another. In addition, when there are a plurality of R^{d21} 's and R^{d41} 's, the plurality of R^{d21} 's and R^{d41} 's may be the same as or different from one another.

[0091] In addition, in the general formula (d1-2), m_2 represents 1 or 2, and in the general formula (d1-4), m_4 represents 1 or 2.

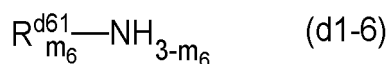
[0092] Examples of the phosphate ester represented by the general formula (d1-1) include triphenyl phosphate, tricresyl phosphate, benzyl diphenyl phosphate, ethyl diphenyl phosphate, tributyl phosphate, ethyl dibutyl phosphate, tert-butyl phenyl diphenyl phosphate, di-tert-butylphenyl monophenyl phosphate, cresyl diphenyl phosphate, dicresyl monophenyl phosphate, ethyl phenyl diphenyl phosphate, diethyl phenyl monophenyl phosphate, triethyl phenyl phosphate, trihexyl phosphate, tri(2-ethylhexyl) phosphate, tridecyl phosphate, trilauryl phosphate, trimyristyl phosphate, tripalmityl phosphate, tristearyl phosphate, and trioleyl phosphate.

[0093] Examples of the acidic phosphate ester represented by the general formula (d1-2) include mono- or di-ethyl acid phosphate, mono- or di-n-propyl acid phosphate, mono- or di-2-ethylhexyl acid phosphate, mono- or di-butyl acid phosphate, mono- or di-oleyl acid phosphate, mono- or di-isodecyl acid phosphate, mono- or di-lauryl acid phosphate, mono- or di-stearyl acid phosphate, and mono- or di-isostearyl acid phosphate.

[0094] Examples of the phosphite ester represented by the general formula (d1-3) include triethyl phosphite, tributyl phosphite, triphenyl phosphite, tricresyl phosphite, tri(nonylphenyl) phosphite, tri(2-ethylhexyl) phosphite, tridecyl phosphite, trilauryl phosphite, triisooctyl phosphite, diphenyl isodecyl phosphite, tristearyl phosphite, and trioleyl phosphite.

[0095] Examples of the hydrogen phosphite ester represented by the general formulas (d1-4) and (d1-5) include mono- or di-ethyl hydrogen phosphite, mono- or di-n-propyl hydrogen phosphite, mono- or di-n-butyl hydrogen phosphite, mono- or di-2-ethylhexyl hydrogen phosphite, mono- or di-lauryl hydrogen phosphite, mono- or di-oleyl hydrogen phosphite, mono- or di-stearyl hydrogen phosphite, and mono- or di-phenyl hydrogen phosphite.

[0096] In addition, preferred examples of the amine salt of the phosphate ester compounds such as the phosphate ester, acidic phosphate ester, phosphite ester and hydrogen phosphite ester include an amine salt formed from the phosphate ester compounds described above and an amine. Here, examples of the amine used for forming the amine salt include a primary amine, a secondary amine, a tertiary amine, and a polyalkylene amine, and examples of the primary amine, the secondary amine, and the tertiary amine include amines represented by the following general formula (d1-6).



[0097] In the general formula (d1-6), R^{d61} represents a hydrocarbon group having 1 to 30 carbon atoms. When the hydrocarbon group is an alkyl group, the hydrocarbon group can be a hydroxyalkyl group in which at least one hydrogen atom in the alkyl group is substituted with a hydroxy group.

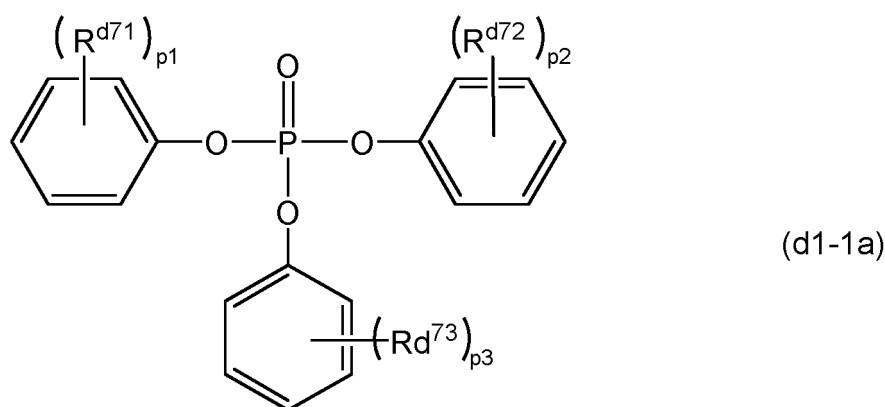
[0098] R^{d61} is preferably an alkyl group having 6 to 18 carbon atoms, an alkenyl group having 6 to 18 carbon atoms, an aryl group having 6 to 18 ring carbon atoms, an arylalkyl group having 7 to 18 carbon atoms, or a hydroxyalkyl group having 6 to 18 carbon atoms. Among these, an alkyl group having 6 to 18 carbon atoms is more preferable.

[0099] In addition, m_6 is 1, 2 or 3, and the amine is a primary amine when m_6 is 1, the amine is a secondary amine when m_6 is 2, and the amine is a tertiary amine when m_6 is 3.

[0100] Examples of the polyalkylene amine include ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenhexamine, hexaethyleneheptamine, heptaethyleneoctamine, tetrapropyleneepentamine, and hexabutyleneheptamine.

[0101] Among these, from the viewpoint of imparting more excellent wear resistance to the lubricating oil composition, it is preferable to use one or more selected from the group consisting of a phosphate ester and an amine salt of an acidic phosphate ester, and it is preferable to use a phosphate ester alone or a combination of phosphate esters and an amine salt of an acidic phosphate ester.

[0102] The phosphate ester is preferably a compound represented by the general formula (d1-1), and more preferably a compound represented by the following general formula (d1-1a).



[0103] In the general formula (d1-1a), R^{d71} to R^{d73} are each independently an alkyl group having 1 to 12 carbon atoms. p_1 to p_3 are each independently an integer of 0 to 5.

[0104] Among compounds represented by the general formula (d1-1a), from the viewpoint of more easily exhibiting the effects of the present invention, R^{d71} to R^{d73} are each independently preferably an alkyl group having 1 to 10 carbon atoms, more preferably an alkyl group having 1 to 6 carbon atoms, and still more preferably an alkyl group having 1 to 4 carbon atoms.

[0105] In addition, it is preferable that p_1 to p_3 are each independently an integer of 0 or 1.

[0106] Here, when a phosphate ester is used alone, it is preferable that one or two of p_1 to p_3 are 0 and the rest is 1. In addition, in this case, the alkyl group that can be selected as R^{d71} to R^{d73} is preferably a tert-butyl group.

[0107] In addition, the amine salt of the acidic phosphate ester is preferably an amine salt of an acidic phosphate ester formed of an acidic phosphate ester represented by the general formula (d1-2) and an amine represented by the general formula (d1-6). In this case, the acidic phosphate ester represented by the general formula (d1-2) is preferably an alkyl group having 2 to 10 carbon atoms, more preferably an alkyl group having 2 to 8 carbon atoms, and still more preferably an alkyl group having 3 to 6 carbon atoms.

(Sulfur-phosphorus-based Extreme Pressure Agent (D2))

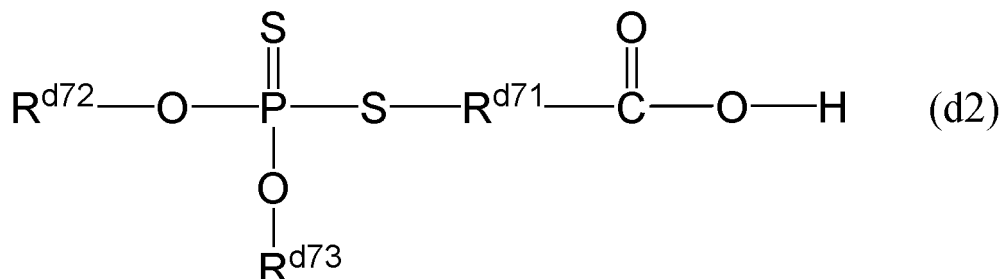
[0108] The lubricating oil composition according to the embodiment of the present invention preferably contains the sulfur-phosphorus-based extreme pressure agent (D2). When the lubricating oil composition contains the sulfur-phosphorus-based extreme pressure agent (D2), excellent wear resistance is easily imparted to the lubricating oil composition. In addition, by using the sulfur-phosphorus-based extreme pressure agent (D2) in combination with the component (B), the component (C1), and the component (C2), a decrease in sludge prevention properties caused by addition of the sulfur-phosphorus-based extreme pressure agent (D2) is alleviated, and thus performance of the sulfur-phosphorus-based extreme pressure agent (D2) is exhibited well.

[0109] Examples of the sulfur-phosphorus-based extreme pressure agent (D2) include a monothiophosphate ester, a dithiophosphate ester, a trithiophosphate ester, an amine salt of the monothiophosphate ester, an amine salt of the

dithiophosphate ester, a monothiophosphite ester, a dithiophosphite ester, and a trithiophosphite ester. Among these, a dithiophosphate ester is preferable.

[0110] Here, from the viewpoint of imparting even more excellent wear resistance to the lubricating oil composition, among the dithiophosphate ester, a dithiophosphate ester having a carboxy group at a terminal is preferable.

[0111] Specific examples of the dithiophosphate ester having a carboxyl group at the terminal include a compound represented by the following general formula (d2).



[0112] In the general formula (d2), $\text{R}^{\text{d}71}$ represents a linear or branched alkylene group having 1 to 8 carbon atoms, and $\text{R}^{\text{d}72}$ and $\text{R}^{\text{d}73}$ each independently represent a hydrocarbon group having 3 to 20 carbon atoms.

[0113] From the viewpoint of improving solubility in the base oil, $\text{R}^{\text{d}71}$ is preferably a linear or branched alkylene group having 1 to 8 carbon atoms, more preferably a linear or branched alkylene group having 2 to 4 carbon atoms, and still more preferably a branched alkylene group. Specifically, preferred examples thereof include $-\text{CH}_2\text{CH}_2-$, $-\text{CH}_2\text{CH}(\text{CH}_3)-$, $-\text{CH}_2\text{CH}(\text{CH}_2\text{CH}_3)-$, $\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2-$, and $-\text{CH}_2\text{CH}(\text{CH}_2\text{CH}_2\text{CH}_3)-$. $-\text{CH}_2\text{CH}(\text{CH}_3)-$ and $-\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2-$ are more preferable, and $-\text{CH}_2\text{CH}(\text{CH}_3)-$ is still more preferable.

[0114] In addition, from the viewpoint of improving extreme pressure performance and improving solubility in the base oil, $\text{R}^{\text{d}72}$ and $\text{R}^{\text{d}73}$ are each preferably a linear or branched alkyl group having 3 to 8 carbon atoms, and more preferably a linear or branched alkyl group having 4 to 6 carbon atoms. Specifically, $\text{R}^{\text{d}72}$ and $\text{R}^{\text{d}73}$ are each preferably selected from the group consisting of a propyl group, an isopropyl group, a butyl group, an isobutyl group, a tert-butyl group, a pentyl group, an isopentyl group, a hexyl group, a 2-ethylbutyl group, a 1-methylpentyl group, a 1,3-dimethylbutyl group, and a 2-ethylhexyl group. Among these, an isobutyl group and a tert-butyl group are more preferable.

[0115] The sulfur-phosphorus-based extreme pressure agent (D2) can be used alone or two or more types of sulfur-phosphorus-based extreme pressure agents (D2) can be used in combination.

(Content of Extreme Pressure Agent (D))

[0116] In the lubricating oil composition according to the embodiment of the present invention, a content of the extreme pressure agent (D) is preferably 0.20% by mass or more, more preferably 0.30% by mass or more, and still more preferably 0.40% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 2.0% by mass or less, more preferably 1.7% by mass or less, and still more preferably 1.5% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.20% by mass to 2.0% by mass, more preferably 0.30% by mass to 1.7% by mass, and still more preferably 0.40% by mass to 1.5% by mass.

[0117] When the content of the extreme pressure agent (D) is equal to or higher than the lower limit value, a lubricating oil composition having excellent wear resistance is easily obtained. In addition, when the content of the extreme pressure agent (D) is equal to or less than the upper limit value, sludge generation caused by the extreme pressure agent (D) is easily prevented.

(Content of Phosphorus-based Extreme Pressure Agent (D 1))

[0118] In the lubricating oil composition according to the embodiment of the present invention, a content of the phosphorus-based extreme pressure agent (D 1) is preferably 0.30% by mass or more, more preferably 0.35% by mass or more, and still more preferably 0.40% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 1.5% by mass or less, more preferably 1.2% by mass or less, and still more preferably 1.0% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.30% by mass to 1.5% by mass, more preferably 0.35% by mass to 1.2% by mass, and still more preferably 0.40% by mass to 1.0% by mass.

[0119] When the content of the phosphorus-based extreme pressure agent (D1) is equal to or higher than the lower

limit value, a lubricating oil composition having excellent wear resistance is easily obtained. In addition, when the content of the phosphorus-based extreme pressure agent (D1) is equal to or less than the upper limit value, sludge generation caused by the phosphorus-based extreme pressure agent (D1) is easily prevented.

[0120] From the same viewpoint, a content of phosphorus atoms derived from the phosphorus-based extreme pressure agent (D1) is preferably 200 ppm by mass to 1400 ppm by mass, more preferably 300 ppm by mass to 900 ppm by mass, and still more preferably 500 ppm by mass to 700 ppm by mass, based on the total amount of the lubricating oil composition.

[0121] Here, as the phosphorus-based extreme pressure agent (D1), it is preferable to use a phosphate ester alone or a combination of a phosphate ester compound and an amine salt of an acidic phosphate ester.

[0122] When the phosphate ester is used alone as the phosphorus-based extreme pressure agent (D1), a content of the phosphate ester is preferably within a range same as the range of the content of the phosphorus-based extreme pressure agent (D1).

[0123] When the phosphate ester compound and the amine salt of the acidic phosphate ester are used in combination as the phosphorus-based extreme pressure agent (D1), a total content of the phosphate ester compound and the amine salt of the acidic phosphate ester is preferably within a range same as the range of the content of the phosphorus-based extreme pressure agent (D1).

[0124] In addition, when the phosphate ester compound and the amine salt of the acidic phosphate ester are used in combination as the phosphorus-based extreme pressure agent (D1), a content of the phosphate ester compound is preferably 0.20% by mass or more, more preferably 0.30% by mass or more, and still more preferably 0.35% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 1.4% by mass or less, more preferably 1.2% by mass or less, and still more preferably 0.9% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.20% by mass to 1.4% by mass, more preferably 0.30% by mass to 1.2% by mass, and still more preferably 0.35% by mass to 0.9% by mass. In addition, a content of the amine salt of the acidic phosphate ester is preferably 0.003% by mass or more, more preferably 0.005% by mass or more, and still more preferably 0.007% by mass or more. In addition, the content is preferably 0.1% by mass or less, more preferably 0.05% by mass or less, and still more preferably 0.03% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.003% by mass to 0.1% by mass, more preferably 0.005% by mass to 0.05% by mass, and still more preferably 0.007% by mass to 0.03% by mass.

[0125] In addition, when the phosphate ester compound and the amine salt of the acidic phosphate ester are used in combination as the phosphorus-based extreme pressure agent (D1), a content ratio of the phosphate ester compound to the amine salt of the acidic phosphate ester $[(\text{phosphate ester compound})/(\text{amine salt of acidic phosphate ester})]$ is preferably 50/1 or more, more preferably 60/1 or more, and still more preferably 70/1 or more in terms of a mass ratio. In addition, the content ratio is preferably 100/1 or less, more preferably 95/1 or less, and still more preferably 90/1 or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content ratio is preferably 50/1 to 100/1, more preferably 60/1 to 95/1, and still more preferably 70/1 to 90/1.

(Content of Sulfur-phosphorus-based Extreme Pressure Agent (D2))

[0126] In the lubricating oil composition according to the embodiment of the present invention, a content of the sulfur-phosphorus-based extreme pressure agent (D2) is preferably 0.01% by mass or more, and more preferably 0.02% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 0.20% by mass or less, more preferably 0.10% by mass or less, and still more preferably 0.07% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.01% by mass to 0.20% by mass, more preferably 0.02% by mass to 0.10% by mass, and still more preferably 0.02% by mass to 0.07% by mass.

[0127] When the content of the sulfur-phosphorus-based extreme pressure agent (D2) is equal to or higher than the lower limit value, a lubricating oil composition having excellent wear resistance is easily obtained. In addition, when the content of the sulfur-phosphorus-based extreme pressure agent (D2) is equal to or less than the upper limit value, sludge generation caused by the sulfur-phosphorus-based extreme pressure agent (D2) is easily prevented.

[0128] From the same viewpoint, a content of phosphorus atoms derived from the sulfur-phosphorus-based extreme pressure agent (D2) is preferably 7 ppm by mass to 250 ppm by mass, more preferably 15 ppm by mass to 150 ppm by mass, and still more preferably 20 ppm by mass to 70 ppm by mass, based on the total amount of the lubricating oil composition.

[0129] In addition, from the same viewpoint, a content of sulfur atoms derived from the sulfur-phosphorus-based extreme pressure agent (D2) is preferably 15 ppm by mass to 500 ppm by mass, more preferably 25 ppm by mass to 250 ppm by mass, and still more preferably 30 ppm by mass to 150 ppm by mass, based on the total amount of the lubricating oil composition.

(Content Ratio [(D1)/(D2)] of Phosphorus-based Extreme Pressure Agent (D1) to Sulfur-phosphorus-based Extreme Pressure Agent (D2))

[0130] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, a content ratio [(D1)/(D2)] of the phosphorus-based extreme pressure agent (D1) to the sulfur-phosphorus-based extreme pressure agent (D2) is preferably 20/3 or more, more preferably 30/3 or more, and still more preferably 40/3 or more in terms of a mass ratio. In addition, the content ratio is preferably 80/3 or less, more preferably 70/3 or less, and still more preferably 60/3 or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content ratio is preferably 20/3 to 80/3, more preferably 30/3 to 70/3, and still more preferably 40/3 to 60/3.

(Another Extreme Pressure Agent (D'))

[0131] In the lubricating oil composition according to the embodiment of the present invention, the extreme pressure agent (D) is not limited to one or more extreme pressure agents selected from the group consisting of the phosphorus-based extreme pressure agent (D1) and the sulfur-phosphorus-based extreme pressure agent (D2), and another extreme pressure agent (D') can also be used.

[0132] Examples of the another extreme pressure agent (D') include an organic metal-based extreme pressure agent and a sulfur-based extreme pressure agent.

[0133] Examples of the organic metal-based extreme pressure agent include one or more selected from organic molybdenum-based compounds such as molybdenum dialkyldithiocarbamate (MoDTC) and molybdenum dialkyldithiophosphate (MoDTP), and organic zinc-based compounds such as zinc dialkyldithiocarbamate (ZnDTC) and zinc dialkyldithiophosphate (ZnDTP).

[0134] Examples of the sulfur-based extreme pressure agent include one or more selected from a sulfurized oil and fat, a sulfurized fatty acid, a sulfurized ester, a sulfurized olefin, a monosulfide, a polysulfide, a dihydrocarbyl polysulfide, a thiadiazole compound, an alkylthiocarbamoyl compound, a thiocarbamate compound, a thioterpene compound, and a dialkyl thiodipropionate compound.

[0135] However, from the viewpoint of making it easier to exhibit the effects of the present invention, a content of the organic metal-based extreme pressure agent and the sulfur-based extreme pressure agent is preferably low.

[0136] Specifically, the content of the organic metal-based extreme pressure agent and the sulfur-based extreme pressure agent is preferably less than 0.1% by mass, more preferably less than 0.01% by mass, and still more preferably less than 0.001% by mass, based on the total amount of the lubricating oil composition, and yet still more preferably, no organic metal-based extreme pressure agent or sulfur-based extreme pressure agent is contained.

<Amine-based Antioxidant (E)>

[0137] The lubricating oil composition according to the embodiment of the present invention preferably further contains an amine-based antioxidant (E). By containing the amine-based antioxidant (E), the sludge prevention properties of the lubricating oil composition are more easily improved.

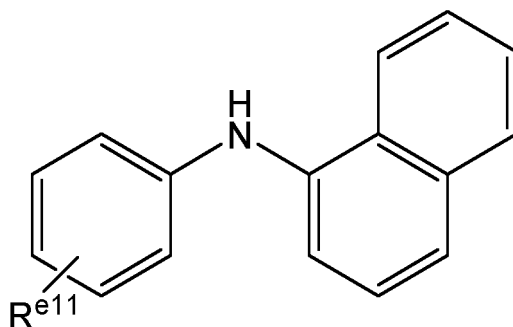
[0138] The amine-based antioxidant (E) that can be used in the lubricating oil composition according to the embodiment of the present invention is not particularly limited, and is preferably, for example, a compound represented by the following general formula (e1).



[0139] [In the general formula (e1), Ar¹ and Ar² each independently represent an aryl group having 6 to 24 carbon atoms selected from a phenyl group, an alkylsubstituted phenyl group substituted with an alkyl group, an aralkyl-substituted phenyl group substituted with an aralkyl group, a naphthyl group, and an alkylsubstituted naphthyl group substituted with an alkyl group.]

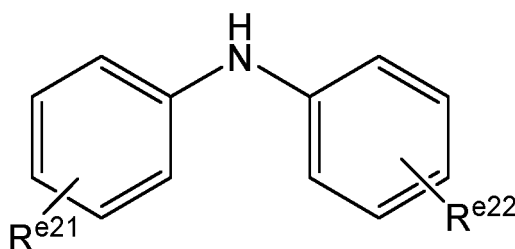
[0140] In addition, more specifically, the amine-based antioxidant (E) is preferably one selected from the group consisting of a phenyl- α -naphthylamine represented by the following general formula (e1-1) and a diphenylamine represented by the following general formula (e1-2).

(e1-1)



[0141] In the general formula (e1-1), R^{e11} is a hydrogen atom or an alkyl group having 1 to 18 carbon atoms.]

(e1-2)



[0142] In the general formula (e1-2), R^{e21} and R^{e22} are each independently selected from a hydrogen atom, an alkyl group having 1 to 18 carbon atoms, and an aralkyl group having 7 to 18 carbon atoms.)

[0143] In the phenyl- α -naphthylamine represented by the general formula (e1-1), R^{e11} is preferably a hydrogen atom or an alkyl group having 1 to 12 carbon atoms, and R^{e11} is preferably located at a para-position.

[0144] In addition, in the diphenylamine represented by the general formula (e1-2), R^{e21} and R^{e22} are each independently preferably selected from a hydrogen atom, an alkyl group having 4 to 12 carbon atoms, and an α,α -dimethylbenzyl group. In addition, it is more preferable that R^{e21} and R^{e22} are both located at a para-position.

[0145] Specific examples of the amine-based antioxidant include, but are not particularly limited to, dioctyldiphenylamine, phenyl- α -naphthylamine, diphenylamine, dinonyldiphenylamine, monobutylphenylmonooctylphenylamine, p-t-octylphenyl-1-naphthylamine, and 4,4'-bis(α,α -dimethylbenzyl)diphenylamine.

[0146] In addition, as the amine-based antioxidant (E), diamine-based antioxidants other than those described above can also be used. Specific examples thereof include N-isopropyl-N'-phenyl-p-phenylenediamine, N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine, N,N'-di-2-naphthyl-p-phenylenediamine, and N-phenyl-N'-(1,3-dimethylbutyl)-p-phenylenediamine.

[0147] As the amine-based antioxidant (E), one amine-based antioxidant can be used alone, or two or more types of amine-based antioxidants can be used in combination.

(Content of Amine-based Antioxidant (E))

[0148] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, a content of the amine-based antioxidant (E) is preferably 0.02% by mass or more, more preferably 0.05% by mass or more, and still more preferably 0.08% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 0.20% by mass or less, more preferably 0.16% by mass or less, still more preferably 0.14% by mass or less, and yet still more preferably 0.12% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.02% by mass to 0.20% by mass, more preferably 0.05% by mass to 0.16% by mass, still more preferably 0.08% by mass to 0.14% by mass, and yet still more preferably 0.08% by mass to 0.12% by mass.

<Content Ratio [(B)/(E)] of Hindered Phenol-based Antioxidant (B) to Amine-based Antioxidant (E)>

[0149] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to exhibit the effects of the present invention, a content ratio [(B)/(E)] of the hindered phenol-based antioxidant (B) to the amine-based antioxidant (E) is preferably 6/1 or more, more preferably 6.5/1 or more, and still more preferably 7/1 or more in terms of a mass ratio. In addition, the content ratio is preferably 10/1 or less, more

preferably 9.5/1 or less, and still more preferably 9/1 or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content ratio is preferably 6/1 to 10/1, more preferably 6.5/1 to 9.5/1, and still more preferably 7/1 to 9/1.

<Sorbitan Fatty Acid Ester (F)>

[0150] The lubricating oil composition according to the embodiment of the present invention preferably further contains a sorbitan fatty acid ester (F). By using the sorbitan fatty acid ester (F) in combination with the imide compound (C), a squeal phenomenon between a hydraulic cylinder and a sealing material (hereinafter, also simply referred to as the "squeal phenomenon") can be prevented without impairing the effects of the present invention.

[0151] The sorbitan fatty acid ester (F) is an ester compound of sorbitan and a fatty acid. The sorbitan fatty acid ester (F) can be a partial ester or a complete ester, and is preferably a partial ester from the viewpoint of making it easier to prevent the squeal phenomenon without impairing the effects of the present invention. That is, the sorbitan fatty acid ester (F) preferably contains one or more selected from the group consisting of a sorbitan fatty acid monoester, a sorbitan fatty acid diester, and a sorbitan fatty acid triester.

[0152] Specifically, a total content of the one or more selected from the group consisting of a sorbitan fatty acid monoester, a sorbitan fatty acid diester, and a sorbitan fatty acid triester is preferably 80% by mass to 100% by mass, more preferably 85% by mass to 100% by mass, still more preferably 90% by mass to 100% by mass, and yet still more preferably 95% by mass to 100% by mass, based on a total amount of the sorbitan fatty acid ester (F).

[0153] Examples of the fatty acid constituting the sorbitan fatty acid ester (F) include a fatty acid having preferably 14 to 22 carbon atoms, and more preferably 16 to 20 carbon atoms. The number of carbon atoms in the fatty acid also includes a carbon atom of a carboxy group (-COOH) in the fatty acid. In addition, the fatty acid can be linear or branched, and is preferably linear.

[0154] Examples of the fatty acid include linear saturated fatty acids such as palmitic acid and stearic acid, and linear unsaturated fatty acids such as oleic acid and elaidic acid. These fatty acids can be used alone or two or more thereof can be used in combination. Among these, from the viewpoint of making it easier to prevent the squeal phenomenon without impairing the effects of the present invention, it is preferable to use a linear unsaturated fatty acid, and it is more preferable to use oleic acid. That is, the sorbitan fatty acid ester (F) more preferably contains one or more selected from the group consisting of sorbitan monooleate, sorbitan dioleate, and sorbitan trioleate, still more preferably contains one or more selected from the group consisting of sorbitan monooleate and sorbitan dioleate, and yet still more preferably contains sorbitan monooleate.

(Content of Sorbitan Fatty Acid Ester (F))

[0155] From the viewpoint of making it easier to prevent the squeal phenomenon without impairing the effects of the present invention, a content of the sorbitan fatty acid ester (F) is preferably 0.02% by mass or more, more preferably 0.05% by mass or more, and still more preferably 0.08% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content is preferably 0.50% by mass or less, more preferably 0.30% by mass or less, still more preferably 0.20% by mass or less, and yet still more preferably 0.15% by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 0.02% by mass to 0.50% by mass, more preferably 0.05% by mass to 0.30% by mass, still more preferably 0.08% by mass to 0.20% by mass, and yet still more preferably 0.08% by mass to 0.15% by mass.

<Content Ratio [(C)/(F)] of Imide Compound (C) to Sorbitan Fatty Acid Ester (F)>

[0156] In the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of making it easier to prevent the squeal phenomenon of the cylinder without impairing the effects of the present invention, a content ratio [(C)/(F)] of the imide compound (C) to the sorbitan fatty acid ester (F) is preferably 1/3 or more, more preferably 1/2 or more, and still more preferably 2/3 or more in terms of a mass ratio. In addition, the content ratio is preferably 7/2 or less, more preferably 6/2 or less, and still more preferably 5/2 or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content ratio is preferably 1/3 to 7/2, more preferably 1/2 to 6/2, and still more preferably 2/3 to 5/2.

<Other Additives>

[0157] The lubricating oil composition according to the embodiment of the present invention can contain lubricating oil additives other than the component (B), the component (C), and the component (D) as long as the effects of the present invention are not impaired.

[0158] Examples of the lubricating oil additives include a viscosity index improver, a pour point depressant, a rust inhibitor, a metal deactivator, an anti-foaming agent, and an antioxidant other than the components (B) and (E).

[0159] These lubricating oil additives can be used alone or two or more thereof can be used in combination.

[0160] In the present description, in consideration of handling properties and solubility in the base oil (A), an additive such as a viscosity index improver or an anti-foaming agent can be in a form of a solution diluted with and dissolved in a part of the base oil (A). In such a case, in the present description, a content to be described later of the additive such as an anti-foaming agent and a viscosity index improver refers to a content in terms of an active ingredient excluding the diluent oil (in terms of resin contents).

(Viscosity Index Improver)

[0161] Examples of the viscosity index improver include polymers such as a non-dispersed polymethacrylate, a dispersed polymethacrylate, an olefin-based copolymer (for example, an ethylene-propylene copolymer), a dispersed olefin-based copolymer, and a styrene-based copolymer (for example, a styrene-diene copolymer and a styrene-isoprene copolymer).

[0162] In a case where the lubricating oil composition according to the embodiment of the present invention contains a viscosity index improver, a content of the viscosity index improver in terms of resin contents is preferably 0.01% by mass to 10% by mass, more preferably 0.02% by mass to 7% by mass, and still more preferably 0.03% by mass to 5% by mass, based on the total amount of the lubricating oil composition.

(Pour Point Depressant)

[0163] Examples of the pour point depressant include a polymethacrylate having a mass average molecular weight of about 50,000 to 150,000. In a case where the lubricating oil composition according to the embodiment of the present invention contains a pour point depressant, a content of the pour point depressant is preferably 0.01% by mass to 5% by mass, and more preferably 0.02% by mass to 2% by mass, based on the total amount of the lubricating oil composition.

[0164] Examples of the rust inhibitor include a metal sulfonate, an alkylbenzene sulfonate, a dinonylnaphthalene sulfonate, an organophosphite ester, an organophosphate ester, an organic sulfonic acid metal salt, an organic phosphoric acid metal salt, an alkenyl succinate ester, and an alkenyl succinate polyhydric alcohol ester.

[0165] In a case where the lubricating oil composition according to the embodiment of the present invention contains a rust inhibitor, a content of the rust inhibitor is preferably 0.01% by mass to 10.0% by mass, and more preferably 0.03% by mass to 5.0% by mass, based on the total amount of the lubricating oil composition.

(Metal Deactivator)

[0166] Examples of the metal deactivator include a benzotriazole-based compound, a tolyltriazole-based compound, a thiadiazole-based compound, an imidazole-based compound, and a pyrimidine-based compound.

[0167] In a case where the lubricating oil composition according to the embodiment of the present invention contains a metal deactivator, a content of the metal deactivator is preferably 0.01% by mass to 5.0% by mass, and more preferably 0.03% by mass to 3.0% by mass, based on the total amount of the lubricating oil composition.

(Anti-foaming Agent)

[0168] Examples of the anti-foaming agent include a silicone-based anti-foaming agent, a fluorine-based anti-foaming agent such as a fluorosilicone oil and a fluoroalkyl ether, and a polyacrylate-based anti-foaming agent.

[0169] In a case where the lubricating oil composition according to the embodiment of the present invention contains an anti-foaming agent, a content of the anti-foaming agent in terms of resin contents is preferably 0.0001% by mass to 0.20% by mass, and more preferably 0.0005% by mass to 0.10% by mass, based on the total amount of the lubricating oil composition.

(Antioxidant Other Than Components (B) and (E))

[0170] Examples of the antioxidant other than the components (B) and (E) include a phenol-based antioxidant other than the component (B), a metal-based antioxidant, and a sulfur-based antioxidant.

[0171] Here, in the lubricating oil composition according to the embodiment of the present invention, from the viewpoint of obtaining a lubricating oil composition having more excellent sludge prevention properties, a content of DBPC is preferably low among phenol-based antioxidants other than the component (B). From the viewpoint of obtaining a lubricating oil composition having more excellent sludge prevention properties, the content of DBPC is preferably less

than 0.60% by mass, more preferably less than 0.10% by mass, and still more preferably less than 0.01% by mass, based on the total amount of the lubricating oil composition, and yet still more preferably, no DBPC is contained.

[0172] In addition, from the viewpoint of more easily exhibiting the effects of the present invention, a content of each of the metal-based antioxidant and the sulfur-based antioxidant is preferably small.

[0173] Specifically, a content of each of the metal-based antioxidant and the sulfur-based antioxidant is preferably less than 0.1% by mass, more preferably less than 0.01% by mass, and still more preferably less than 0.001% by mass, based on the total amount of the lubricating oil composition, and yet still more preferably, no metal-based antioxidant or sulfur-based antioxidant is contained.

[Various Physical Properties of Lubricating Oil Composition]

<Kinematic Viscosity at 40°C>

[0174] A kinematic viscosity at 40°C of the lubricating oil composition according to the embodiment of the present invention is preferably 10 mm²/s or more, more preferably 15 mm²/s or more, and still more preferably 20 mm²/s or more. In addition, the kinematic viscosity at 40°C is preferably 150 mm²/s or less, more preferably 100 mm²/s or less, and still more preferably 80 mm²/s or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the kinematic viscosity at 40°C is preferably 10 mm²/s to 150 mm²/s, more preferably 15 mm²/s to 100 mm²/s, and still more preferably 20 mm²/s to 80 mm²/s.

[0175] When the kinematic viscosity at 40°C of the lubricating oil composition is 10 mm²/s or more, a lubricating oil composition having a high flash point and excellent lubricating performance is easily obtained.

[0176] In addition, when the kinematic viscosity at 40°C of the base oil (A) is 150 mm²/s or less, viscosity resistance at a low temperature is not excessively large, and thus an operation of a machine is easily improved.

<Viscosity Index>

[0177] A viscosity index of the lubricating oil composition according to the embodiment of the present invention is preferably 80 or more, more preferably 90 or more, still more preferably 100 or more, and yet still more preferably 110 or more.

<Sludge Prevention Properties>

[0178] In the lubricating oil composition according to the embodiment of the present invention, a millipore value measured and calculated according to SAE-ARP-785-63 after performing a high pressure piston pump test described in Examples to be described later for 2,000 hours according to JCMAS P045 is preferably 10 mg/100 mL or less, more preferably 5.0 mg/100 mL or less, still more preferably 4.0 mg/mL or less, and yet still more preferably 3.5 mg/100 mL.

[0179] The lubricating oil composition of the present invention has an extremely low millipore value after the high pressure piston pump test is performed for a long time of 2,000 hours, and is thus extremely excellent in sludge prevention properties.

<Wear Resistance>

(Scoring Resistance)

[0180] In the lubricating oil composition according to the embodiment of the present invention, a stage value measured by an FZG scoring test described in Examples to be described later according to ASTM D5182-97 (2014) is preferably 10 stage or more after the high pressure piston pump test described in Examples to be described later according to JCMAS P045 is performed for 2,000 hours.

[0181] The lubricating oil composition of the present invention has a high stage value in the FZG scoring test after the high pressure piston pump test is performed for a long time of 2,000 hours, and is thus extremely excellent in scoring resistance.

(Seizure Resistance)

[0182] In the lubricating oil composition according to the embodiment of the present invention, a seizure load measured by an SRV (oscillation, friction and wear) test described in Examples to be described later according to ASTM D7421 is preferably 1,500 N or more, and more preferably 1,600 N or more after the high pressure piston pump test described in Examples to be described later according to JCMAS P045 is performed for 2,000 hours.

[0183] The lubricating oil composition of the present invention has a high seizure load in the SRV (oscillation, friction and wear) test after the high pressure piston pump test is performed for a long time of 2,000 hours, and is thus extremely excellent in seizure resistance.

5 [Method of Producing Lubricating Oil Composition]

[0184] A method of producing the lubricating oil composition of the present invention is not particularly limited.

[0185] For example, a method of producing the lubricating oil composition according to the embodiment of the present invention includes a step of mixing the base oil (A), the hindered phenol-based antioxidant (B), one or more imide compounds (C) selected from the group consisting of the monoimide compound (C1) and the bisimide compound (C2), and the extreme pressure agent (D), in which the hindered phenol-based antioxidant (B) is 2,6-di-tert-butylphenol, the monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound, and the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound.

[0186] A method of mixing the components is not particularly limited, and examples thereof include a method including a step of blending the component (B), the component (C), and the component (D) with the base oil (A). The component (B), the component (C), and the component (D) can be blended with the base oil (A) at the same time, or can be blended separately. The same applies to components other than the component (B), the component (C), and the component (D). Each component can be blended in a form of a solution (dispersion) in which a diluent oil or the like is added. After the components are blended, it is preferable to uniformly disperse the mixture by stirring according to a known method.

[Use of Lubricating Oil Composition]

[0187] The lubricating oil composition of the present invention is excellent in sludge prevention properties and wear resistance even when used under a high pressure for a long period of time. Therefore, the lubricating oil composition of the present invention can be used in one or more types of hydraulic equipment selected from the group consisting of a construction machine, a general industrial machine, and a generator. Among these types of hydraulic equipment, the lubricating oil composition of the present invention can be preferably used in hydraulic equipment having an operating pressure of 30 MPa or more.

[0188] Therefore, according to the present invention, the following use methods are provided.

[0189] A method of using the lubricating oil composition of the present invention in hydraulic equipment.

[0190] A method of using the lubricating oil composition of the present invention in one or more types of hydraulic equipment selected from the group consisting of a construction machine, a general industrial machine, and a generator.

[0191] A method of using the lubricating oil composition of the present invention in one or more types of hydraulic equipment each of which has an operating pressure of 30 MPa or more and is selected from the group consisting of a construction machine, a general industrial machine, and a generator.

[0192] Examples of the construction machine include: cranes such as mobile cranes, stationary cranes, and derricks; excavation machines such as hydraulic excavators, mini-excavators, and wheel hydraulic excavators; terrain machines such as bulldozers; loading machines such as wheel loaders; transport machines such as rough terrain transport vehicles; compaction machines such as vibratory rollers; dismantling machines such as breakers; basic construction machines such as pile drivers and earth augers; concrete asphalt machines such as concrete pump vehicles; aerial work platforms, paving machines, shields, boring machines, and snow removal machines.

[0193] In addition, examples of the general industrial machines include vehicles, machine tools, gear devices, conveying devices, air conditioning facilities, and mining facilities.

[Provided One Embodiment of Present Invention]

[0194] In one embodiment of the present invention, the following [1] to [8] are provided.

[1] A lubricating oil composition containing: a base oil (A); a hindered phenol-based antioxidant (B); one or more imide compounds (C) selected from the group consisting of a monoimide compound (C1) and a bisimide compound (C2); and an extreme pressure agent (D), in which the hindered phenol-based antioxidant (B) is 2,6-di-tert-butylphenol, the monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound, and the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound.

[2] The lubricating oil composition according to [1], further containing: an amine-based antioxidant (E).

[3] The lubricating oil composition according to [2], in which a content ratio [(B)/(E)] of the hindered phenol-based antioxidant (B) to the amine-based antioxidant (E) is 6/1 to 10/1 in terms of a mass ratio.

[4] The lubricating oil composition according to any one of [1] to [3], in which a content ratio [(C 1)/(C2)] of the monoimide compound (C 1) to the bisimide compound (C2) is more than 0 and is 2/1 or less in terms of a mass ratio.

[5] The lubricating oil composition according to any one of [1] to [4], in which a content of 2,6-di-tert-butyl-p-cresol is less than 0.60% by mass based on a total amount of the lubricating oil composition.

[6] The lubricating oil composition according to any one of [1] to [5], in which the extreme pressure agent (D) is one or more selected from the group consisting of a phosphorus-based extreme pressure agent (D1) and a sulfur-phosphorus-based extreme pressure agent (D2).

[7] The lubricating oil composition according to any one of [1] to [6], further containing: a sorbitan fatty acid ester (F).

[8] The lubricating oil composition according to any one of [1] to [7], which is used as a hydraulic oil.

[Examples]

[0195] The present invention will be described in detail with reference to the following Examples, whereas the present invention is not limited to the following Examples.

[Method of Measuring Various Physical Property Values]

[0196] Properties of raw materials used in Examples and Comparative Examples and lubricating oil compositions in Examples and Comparative Examples were measured in the following manner.

(1) Kinematic Viscosity and Viscosity Index

[0197] Measurement and calculation were performed according to JIS K2283:2000.

(2) Base Number

[0198] Measurement was performed by a perchloric acid method according to JIS K-2501-9:2003.

[Examples 1 and 2 and Comparative Examples 1 to 3]

[0199] Base oils and various additives shown below were sufficiently mixed in blending amounts (% by mass) shown in Table 1 to prepare lubricating oil compositions.

[0200] Details of the base oils and various additives used in Examples 1 and 2 and Comparative Examples 1 to 3 are as follows.

<Base oil (A)>

[0201] The base oil is a mixed base oil containing a mineral oil belonging to Group II and a mineral oil belonging to Group III in the API category, and the base oils used in Example 1 and Comparative Examples 1 and 2 each have a kinematic viscosity at 40°C of 46 mm²/s and a viscosity index of 120. In addition, the base oils used in Example 2 and Comparative Example 3 each have a kinematic viscosity at 40°C of 68 mm²/s and a viscosity index of 150.

[0202] The kinematic viscosity at 40°C and the viscosity index were measured and calculated according to JIS K2283:2000.

<Hindered Phenol-based Antioxidant (B)>

[0203] 2,6-di-tert-butylphenol (DTBP) was used as the hindered phenol-based antioxidant (B).

<Phenol-based Antioxidant (B')>

[0204] 2,6-di-tert-butyl-p-cresol (DBPC) was used as a phenol-based antioxidant (B') in Comparative Examples.

<Imide Compound (C)>

[0205] As the monoimide compound (C1), a polybutenyl succinic monoimide compound having a polybutenyl group having a mass average molecular weight (Mw) of 6,300, a nitrogen atom content of 1.75% by mass, and a base number of 40.0 mgKOH/g was used.

[0206] In addition, as the bisimide compound (C2), a polybutenyl succinic bisimide compound having a polybutenyl

group having a mass average molecular weight (Mw) of 1,000, a nitrogen atom content of 1.15% by mass, and a base number of 19.5 mgKOH/g was used.

[0207] The mass average molecular weight of the polybutenyl group is a value obtained by measuring a mass average molecular weight (Mw) of a polybutene that is a raw material of the polybutenyl group under the following conditions and evaluating the measured mass average molecular weight as a mass average molecular weight (Mw) in terms of a standard polystyrene.

- SEC device: HLC-8220GPC manufactured by Tosoh Corporation
- Column: TSK guard column HXL-H + two TSK gel GMH-XL + one G2000H-XL, manufactured by Tosoh Corporation
- Solvent: tetrahydrofuran (stabilizer-free special grade, manufactured by Wako Pure Chemical Industries, Ltd.)
- Detector: differential refractive index (RI) detector and UV detector
- Concentration: 0.1 w/v%
- Injection amount: 100 pL
- Flow Rate: 1.0 mL/min
- Column Temperature: 40°C
- Standard sample for calibration curve: TSK standard polystyrene manufactured by Tosoh Corporation
- Analysis software: GPC-8020 model 2

<Extreme Pressure Agent (D)>

(Phosphorus-based Extreme Pressure Agent (D1))

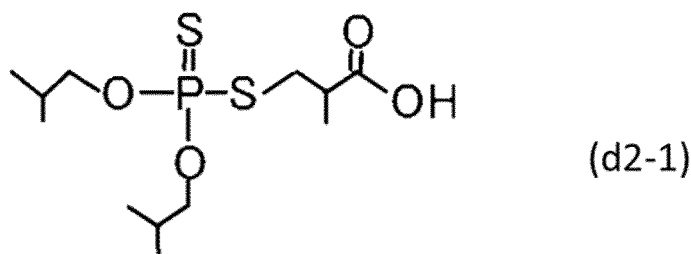
[0208] Phosphate ester compound 1: mixture of tert-butylphenyl diphenyl phosphate and di-tert-butylphenyl monophenyl phosphate

[0209] Phosphate ester compound 2: tricresyl phosphate

[0210] Amine salt of acidic phosphate ester: VANLUBE 672 manufactured by Vanderbilt Chemicals, LLC.

(Sulfur-phosphorus-based Extreme Pressure Agent (D2))

[0211] A compound represented by the following formula (d2-1) (IRGALUBE 353, manufactured by BASF) was used.



[0212] The compound represented by the formula (d2-1) is a compound represented by the general formula (d2) in which R^{d71} is $-\text{CH}_2\text{CH}(\text{CH}_3)-$ and R^{d72} and R^{d73} are isobutyl groups.

<Amine-based Antioxidant (E)>

[0213] Monobutylphenyl monoctylphenylamine (IRGANOX L-57, manufactured by BASF) was used.

[0214] Monobutylphenyl monoctylphenylamine is a compound represented by the general formula (e1-2) in which one of R^{e21} and R^{e22} is a butyl group and the other is an octyl group.

<Sorbitan Fatty Acid Ester (F)>

[0215] Sorbitan monooleate

<Other Additives>

Metal deactivator: benzotriazole

[0216]

Anti-foaming agent: silicone-based anti-foaming agent

·Viscosity index improver: polymethacrylate having a mass average molecular weight (Mw) of 40,000

·Pour point depressant: polymethacrylate having a mass average molecular weight (Mw) of 69,000

[0217] In Example 1 and Comparative Example 3, 0.02 wt% of the metal deactivator, 0.10% by mass of the silicone-based anti-foaming agent in terms of resin contents, 10% by mass of the viscosity index improver, and 0.30% by mass of the pour point depressant were added.

[0218] In Example 2, Comparative Example 1, and Comparative Example 2, 0.02 wt% of the metal deactivator, 0.10% by mass of the silicone-based anti-foaming agent in terms of resin contents, 2.0% by mass of the viscosity index improver, and 0.30% by mass of the pour point depressant were added.

[Evaluation]

[0219] Oxidation deterioration and reduction in wear resistance of the lubricating oil compositions in Examples 1 and 2 and Comparative Examples 1 to 3 when used under a high pressure for a long period of time were evaluated.

[0220] First, for each of the lubricating oil compositions in Examples 1 and 2 and Comparative Examples 1 to 3, a high pressure piston pump test was performed according to JCMAS P045 for 2,000 hours using a high pressure piston pump test device (pump: BOSCH-REXROTH A2F10) under conditions of a pump pressure of 35 MPa, a sample oil temperature of 80°C, and an air blowing amount of 1.0 L/h to obtain a sample oil assuming to be a lubricating oil composition to be used under a high pressure for a long period of time.

[0221] Then, the sample oil was subjected to a millipore value evaluation, an FZG scoring test, and an SRV (oscillation, friction and wear) test.

<Millipore Value Evaluation>

[0222] According to SAE-ARP-785-63, a precipitate in 300 mL of the sample oil was collected by filtration, and the mass of the precipitate per 100 mL of the sample oil was calculated as a "millipore value".

[0223] It can be said that, as the "millipore value" becomes lower, an amount of sludge generated is lower and the lubricating oil composition is more excellent in sludge prevention properties.

[0224] In the present example, a case where the millipore value was 10 mg/100 mL or less was determined to be acceptable.

<FZG Scoring Test>

[0225] According to ASTM D5182-97 (2014), a load was increased stepwise according to the specification under conditions of a sample oil temperature of 90°C, a rotation speed of 1,450 rpm, and an operation time of 15 minutes by using an A-type gear, and a stage of the load when scoring occurred was determined. It can be said that, as a value of the stage becomes higher, scoring resistance is more excellent.

[0226] In the present example, a case where the stage was 10 or more was determined to be acceptable.

<SRV (Oscillation, Friction and Wear) Test>

[0227] A seizure load (N) was measured according to ASTM D7421. As for the seizure load, a load was increased by 100 N at a time under friction conditions of a temperature of 120°C, a frequency of 50 Hz, and an amplitude of 2.0 mm, and a load (N) at the time when seizure occurred and a friction coefficient increased greatly was measured. It can be said that, as a value of the seizure load becomes higher, seizure resistance is more excellent.

[0228] In the present example, a case where the seizure load was 1,500 N or more was determined to be acceptable.

[0229] Results are shown in Table 1.

Table 1

Comprehensive Lubricant Analysis Report								
Category	Base oil (A)		Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3	
	Phenol-based antioxidant (B)	DTBP	87.85	95.57	95.78	95.77	87.85	
Composition of lubricating oil composition (unit: % by mass)	Phenol-based antioxidant (B')	DBPC	-	-	0.60	0.60	-	
	Imide compound (C)	Monoimide compound (C1)	0.10	0.10	-	-	0.20	
		Polybutenyl succinic bisimide (C2)	0.10	0.10	0.10	0.10	-	
	Extreme pressure agent (D)	Phosphorus-based extreme pressure agent (D1)	Phosphate ester compound 1	0.50	-	-	-	0.50
			Phosphate ester compound 2	-	0.80	0.80	0.80	-
		Sulfur-phosphorus-based extreme pressure agent (D2)	Amine salt of acidicphosphate ester	-	0.01	-	0.01	-
			Sulfur-phosphorus-based extreme pressure agent (D2)	0.03	-	-	-	0.03
	Amine-based antioxidant (E)	0.10	0.10	0.20	0.20	0.10		
	Sorbitan fatty acid ester (F)	0.10	0.10	0.10	0.10	0.10		
	Other additives	10.42	2.42	2.42	2.42	10.42		
Various content ratios	Total	100.00	100.00	100.00	100.00	100.00		
	[(B)/(E)]	8.00	8.00	0.00	0.00	8.00		
	[(C1)/(C2)]	1.00	1.00	0.00	0.00	-		
Physical properties of lubricating oil composition	Kinematic viscosity at 40°C (mm²/s)	61.93	47.44	48.95	47.46	62.01		
	Viscosity index	152	125	123	126	152		
	Millipore value (unit: mg/100 mL)	2.1	0.5	19	22	2.1		
Evaluation result	FZG test (unit: stage)	12	10	9	10	10		
	SRV test (unit: N)	1600	1800	1600	1000	1200		

[0230] The following can be seen from Table 1.

[0231] It can be seen that the lubricating oil compositions in Examples 1 and 2 have a small millipore value and are excellent in sludge prevention properties. In addition, it can be seen that since scoring resistance and seizure resistance thereof are also excellent, wear resistance thereof is also excellent.

[0232] In contrast, it can be seen that, as in the lubricating oil compositions in Comparative Examples 1 and 2, when no hindered phenol-based antioxidant (B) is contained and no monoimide compound (C1) is contained, the millipore value is large and the sludge prevention properties are inferior. In addition, it can also be seen that the scoring resistance and seizure resistance thereof are both inferior, and thus the wear resistance thereof is inferior.

[0233] In addition, the lubricating oil composition in Comparative Example 3, which has the same composition as that of Example 1 except that no monoimide compound (C1) is contained and the content of the bisimide compound (C2) is 0.20% by mass, has a small millipore value and excellent sludge prevention properties, whereas seizure resistance thereof is inferior, and thus wear resistance thereof is inferior.

Claims

1. A lubricating oil composition comprising:

a base oil (A);

a hindered phenol-based antioxidant (B);

one or more imide compounds (C) selected from the group consisting of a monoimide compound (C 1) and a bisimide compound (C2); and

an extreme pressure agent (D), wherein

the hindered phenol-based antioxidant (B) is 2,6-di-tert-butylphenol,

the monoimide compound (C1) is one or more selected from the group consisting of an alkenyl succinic monoimide compound and an alkyl succinic monoimide compound, and

the bisimide compound (C2) is one or more selected from the group consisting of an alkenyl succinic bisimide compound and an alkyl succinic bisimide compound.

2. The lubricating oil composition according to claim 1, further comprising:
an amine-based antioxidant (E).

3. The lubricating oil composition according to claim 2, wherein a content ratio [(B)/(E)] of the hindered phenol-based antioxidant (B) to the amine-based antioxidant (E) is 6/1 to 10/1 in terms of a mass ratio.

4. The lubricating oil composition according to any one of claims 1 to 3, wherein a content ratio [(C 1)/(C2)] of the monoimide compound (C 1) to the bisimide compound (C2) is more than 0 and 2/1 or less in terms of a mass ratio.

5. The lubricating oil composition according to any one of claims 1 to 4, wherein a content of 2,6-di-tert-butyl-p-cresol is less than 0.60% by mass based on a total amount of the lubricating oil composition.

6. The lubricating oil composition according to any one of claims 1 to 5, wherein the extreme pressure agent (D) is one or more selected from the group consisting of a phosphorus-based extreme pressure agent (D1) and a sulfur-phosphorus-based extreme pressure agent (D2).

7. The lubricating oil composition according to any one of claims 1 to 6, further comprising:
a sorbitan fatty acid ester (F).

8. The lubricating oil composition according to any one of claims 1 to 7, which is used as a hydraulic oil.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/013183

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A. CLASSIFICATION OF SUBJECT MATTER

C10M 169/04(2006.01)i; C10N 30/04(2006.01)n; C10N 30/06(2006.01)n; C10N 40/08(2006.01)n; C10M 129/10(2006.01)i; C10M 129/74(2006.01)i; C10M 133/12(2006.01)i; C10M 133/16(2006.01)i; C10M 133/56(2006.01)i

FI: C10M129/10; C10M133/16; C10M133/56; C10M169/04; C10M133/12; C10M129/74; C10N40:08; C10N30:04; C10N30:06

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

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C10M169/04; C10N30/04; C10N30/06; C10N40/08; C10M129/10; C10M129/74; C10M133/12; C10M133/16; C10M133/56

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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	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009-543903 A (THE LUBRIZOL CORPORATION) 10 December 2009 (2009-12-10) claims, paragraphs [0016]-[0121], examples 10, etc.	1-8
X A	JP 2004-331933 A (TONENGENERAL SEKIYU KABUSHIKI KAISHA) 25 November 2004 (2004-11-25) claims, paragraphs [0081]-[0091], examples, etc.	1-3, 5-6, 8 4, 7
X	JP 2004-123938 A (ASAHI DENKA KOGYO KK.) 22 April 2004 (2004-04-22) claims, paragraphs [0058]-[0085], example 8, etc.	1-8
X	JP 2004-35577 A (ASAHI DENKA KOGYO KK.) 05 February 2004 (2004-02-05) claims, paragraphs [0008]-[0059], example 11, etc.	1-8

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

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* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"I" 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

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Date of the actual completion of the international search
31 May 2021 (31.05.2021)

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Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
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Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/013183

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2018/003815 A1 (ADEKA CORPORATION) 04 January 2018 (2018-01-04) claims, paragraphs [0028]-[0067], examples 1-8, etc.	1-8
X	JP 2009-29968 A (JAPAN ENERGY CORP.) 12 February 2009 (2009-02-12) claims, paragraphs [0022]-[0057], examples 1, 3, 5, 7, etc.	1-8
X A	WO 2018/003812 A1 (ADEKA CORPORATION) 04 January 2018 (2018-01-04) claims, paragraphs [0033]-[0074], example 16, etc.	1-7 8
A	WO 2016/152752 A1 (IDEMITSU KOSAN CO., LTD.) 29 September 2016 (2016-09-29) claims, examples, etc.	1-8
A	WO 2019/077961 A1 (IDEMITSU KOSAN CO., LTD.) 25 April 2019 (2019-04-25) claims, examples, etc.	1-8

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2021/013183

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WO 2016/152752 A1	29 Sep. 2018	US 2018/0282655 A1 claims, examples, etc. EP 3272841 A1 CN 107429183 A	
WO 2019/077961 A1	25 Apr. 2019	CN 110892049 A claims, examples, etc.	

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REFERENCES CITED IN THE DESCRIPTION

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