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(54) **LUBRICATING OIL COMPOSITION**

(57) An object of the present invention is to provide a lubricating oil composition which is excellent in both long-term anti-foaming performance and detergency while blending a silicone-based anti-foaming agent. The object is achieved by using a lubricating oil composition

containing a base oil (A) and a silicone-based anti-foaming agent (B). A silicon atom content is 50 ppb by mass to 4,000 ppb by mass based on a total amount of the lubricating oil composition.

EP 4 130 212 A1

Description

Technical Field

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

Background Art

10 **[0002]** A lubricating oil composition has a friction reducing effect, a sealing effect, an rust and corrosion inhibiting effect, a cooling effect, a power transmission effect, and the like in various machine devices, and is widely used in various fields.

[0003] Incidentally, during operation of a machine device, the lubricating oil composition may cause foaming due to entrainment of air and the like. Foams generated in the lubricating oil composition lead to a decrease in lubrication performance, a decrease in sealing performance, promotion of oxidative degradation, a decrease in cooling efficiency, a decrease in power transmission efficiency, and the like.

15 **[0004]** Therefore, an anti-foaming agent is blended into the lubricating oil composition as a countermeasure against foaming. As a representative example of the anti-foaming agent to be blended in the lubricating oil composition, a silicone-based anti-foaming agent is known (for example, see PTLs 1 and 2).

20 Citation List

Patent Literature

25 **[0005]**

PTL 1: JP 2020-026447 A

PTL 2: JP 2017-066220 A

Summary of Invention

30 **[0006]** However, as a result of intensive studies, the present inventor has been found that the silicone-based anti-foaming agent can impart anti-foaming performance to the lubricating oil composition over a long period of time but has a problem in deteriorating detergency of the lubricating oil composition.

[0007] In the present invention, the detergency of the lubricating oil composition means detergency evaluated by a pollution degree code in conformity with ISO 4406:1999.

35 **[0008]** The present invention has been made in view of such a problem, and an object of the present invention is to provide a lubricating oil composition which is excellent in both long-term anti-foaming performance and detergency while blending a silicone-based anti-foaming agent.

Solution to Problem

40 **[0009]** As a result of intensive studies, the present inventor has found that the above problems can be solved by adjusting a silicon atom content in a lubricating oil composition containing a silicone-based anti-foaming agent to a specific range.

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

50 [1] A lubricating oil composition containing:

a base oil (A); and
a silicone-based anti-foaming agent (B), in which
a silicon atom content is 50 ppb by mass to 4,000 ppb by mass based on a total amount of the lubricating oil composition.

Advantageous Effects of Invention

55 **[0011]** According to the present invention, it is possible to provide a lubricating oil composition which is excellent in

both long-term anti-foaming performance and detergency while blending a silicone-based anti-foaming agent.

Description of Embodiments

[0012] 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 and 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".

[0013] 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.

[0014] In the present description, a numerical range expressed as "AA to BB" means "AA or more and BB or less" unless otherwise specified.

[Aspect of Lubricating Oil Composition of Present Invention]

[0015] A lubricating oil composition of the present invention contains a base oil (A) and a silicone-based anti-foaming agent (B). A silicon atom content is 50 ppb by mass to 4,000 ppb by mass based on a total amount of the lubricating oil composition.

[0016] The present inventor has intensively studied to provide a lubricating oil composition which is excellent in both long-term anti-foaming performance and detergency while blending a silicone-based anti-foaming agent.

[0017] First, the present inventor has studied various factors that deteriorate the detergency of the lubricating oil composition containing the silicone-based anti-foaming agent. As a result, it is found that when an amount of the silicone-based anti-foaming agent (about 1% by mass based on the total amount of the lubricating oil composition and about 10 ppm by mass in terms of silicon atom) which is expected to maintain anti-foaming performance is blended in the lubricating oil composition in the related art, the detergency evaluated in conformity with ISO 4406:1999 is deteriorated, and the standard is not satisfied. As a result of studying the cause thereof in detail, it is found that in ISO 4406:1999, in order to grasp a contaminant distribution state in a sample by counting microparticles in the sample, silicone particles, which are active components in the silicone-based anti-foaming agent, are measured as microparticles, and as a result, the detergency evaluated in conformity with ISO 4406:1999 is deteriorated, and the standard is not satisfied.

[0018] Based on these problems, the present inventor has further conducted studies, and as a result, it is surprisingly clear that the long-term anti-foaming performance is ensured even when a blending amount of the silicone-based anti-foaming agent is significantly reduced. In addition, by significantly reducing the blending amount of the silicone-based anti-foaming agent, the number of silicone particles is decreased, and the detergency is also improved. Therefore, the present inventor has found a range in which a lubricating oil composition excellent in both long-term anti-foaming performance and detergency can be obtained as a result of investigating the content of the silicone-based anti-foaming agent, and has thus completed the present invention.

[0019] In the following description, the "base oil (A)" and the "silicone-based anti-foaming agent (B)" are also referred to as a "component (A)" and a "component (B)", respectively.

[0020] The lubricating oil composition according to one aspect of the present invention may contain only the component (A) and the component (B), or may contain components other than the component (A) and the component (B) as long as the effects of the present invention are not impaired.

[0021] In the lubricating oil composition according to the aspect of the present invention, a total content of the component (A) and the component (B) is preferably 75% by mass or more, more preferably 80% by mass or more, and still more preferably 85% by mass or more, based on the total amount of the lubricating oil composition.

[0022] An upper limit value of the total content of the component (A) and the component (B) may be adjusted in balance with the components other than the component (A) and the component (B), and is preferably 94.9% by mass or less, more preferably 94% by mass or less, still more preferably 92% by mass or less, and yet still more preferably 90% by mass or less, based on the total amount of the lubricating oil composition.

[0023] Each component contained in the lubricating oil composition of the present invention will be described in detail below.

<Base Oil (A)>

[0024] As the base oil (A), a base oil used as a lubricating base oil in the related art can be used without any limitation, and for example, one or more selected from the group consisting of a mineral oil and a synthetic oil can be used.

[0025] 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 purification treatment such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, and hydrotreating.

[0026] The mineral oil may be used either alone or in combination of two or more thereof.

[0027] Examples of the synthetic oil include a hydrocarbon-based oil, an aromatic oil, an ester-based oil, an ether-based oil, and a base oil in which a temperature gradient $\Delta|Dt|$ of a distillation temperature between two points, i.e., a distillation amount of 2.0 vol% and a distillation amount of 5.0 vol%, in a distillation curve is 6.8°C/vol% or less (preferably a base oil in which a saturated content in a clay gel method measured in conformity with ASTM D-2007 is 90% by mass or more, a sulfur content measured in conformity with ASTM D1552 is 0.03% by mass or less, and a viscosity index obtained in conformity with ASTM D2270 is 120 or more).

[0028] In the present description, the temperature gradient $\Delta|Dt|$ of the distillation temperature between two points, i.e., a distillation amount of 2.0 vol% and a distillation amount of 5.0 vol%, in the distillation curve means a value calculated according to the following equation.

$$\begin{aligned} & \cdot \text{Temperature gradient } \Delta|Dt| \text{ (}^\circ\text{C/vol}\%) = |[\text{distillation temperature (}^\circ\text{C)} \\ & \text{at which distillation amount of base oil is 5.0 vol}\%] - [\text{distillation temperature (}^\circ\text{C)} \\ & \text{at which distillation amount of base oil is 2.0 vol}\%]| / 3.0 \text{ (vol}\%) \end{aligned}$$

[0029] The "distillation temperature (°C) at which distillation amount of base oil is 5.0 vol% or 2.0 vol%" in the above equation is a value measured by a method in conformity with ASTM D6352, specifically means a value measured by a method described in Examples.

[0030] The temperature gradient $\Delta|Dt|$ is preferably 6.5°C/vol% or less, more preferably 6.3°C/vol% or less, still more preferably 6.0°C/vol% or less, and yet still more preferably 5.0°C/vol% or less.

[0031] The temperature gradient $\Delta|Dt|$ is usually 0.1°C/vol% or more.

[0032] The distillation temperature at which the distillation amount is 2.0 vol% in the distillation curve is preferably 405°C to 510°C, more preferably 410°C to 500°C, still more preferably 415°C to 490°C, and yet still more preferably 430°C to 480°C.

[0033] The distillation temperature at which the distillation amount is 5.0 vol% in the distillation curve is preferably 425°C to 550°C, more preferably 430°C to 520°C, still more preferably 434°C to 500°C, and yet still more preferably 450°C to 490°C.

[0034] Aparaffin content (%C_P) in the base oil, in which the temperature gradient $\Delta|Dt|$ of the distillation temperature between two points, i.e., a distillation amount of 2.0 vol% and a distillation amount of 5.0 vol%, in the distillation curve is 6.8°C/vol% or less, is usually 50 or more, preferably 55 or more, more preferably 60 or more, still more preferably 65 or more, yet still more preferably 70 or more, and even still more preferably 80 or more, and is usually 99 or less.

[0035] In the present description, the paraffin content (%C_P) means a value measured in conformity with ASTM D-3238 ring analysis (n-d-M method).

[0036] Here, the temperature gradient defined by the above requirement is a parameter in consideration of a relationship between a state of the base oil, such as a content of a light component and a structure of a wax component which cannot be removed even in a purification step performed by performing one or more purification treatments, and a flash point when the base oil is used as the lubricating oil composition. Since a distillation amount of 2.0 vol% to 5.0 vol% is a temperature region where the variation of the distillation curve is stabilized and the light component also remains, the state of the light component and the wax component in the base oil can be accurately evaluated.

[0037] The synthetic oil may be used either alone or in combination of two or more thereof.

[0038] In the lubricating oil composition according to the aspect of the present invention, the base oil (A) may be one type selected from a mineral oil or one type selected from a synthetic oil, or may be one type selected from a mineral oil in which foaming easily occurs.

[0039] In addition, the base oil (A) may be a mixed base oil obtained by mixing two or more selected from the group consisting of a mineral oil and a synthetic oil. The base oil used in the lubricating oil composition may be a mixed base oil obtained by mixing two or more base oils from the viewpoint of improving various performances required for the lubricating oil composition and the like. On the other hand, in the mixed base oil obtained by mixing two or more base oils, foaming is particularly likely to occur. According to the present invention, it is possible to provide a lubricating oil composition which is excellent in both long-term anti-foaming performance and detergency, even for the mixed base oil in which foaming is particularly likely to occur.

[0040] The two or more base oils may be a combination of two or more base oils having different oil types, and may be a combination of two or more base oils having the same oil type but having different physical property values (for example, a kinematic viscosity at 40°C). In addition, the base oil may be a combination of two or more base oils having the same oil type but having different physical property values (for example, a kinematic viscosity at 40°C) and one or

more base oils having different oil types from the base oil.

[0041] Here, the base oil (A) may be a mixed base oil obtained by combining a high-viscosity base oil (AH) and a low-viscosity base oil (AL). In addition, the base oil (A) may be a mixed base oil obtained by further combining another base oil (AZ) in addition to the high-viscosity base oil (AH) and the low-viscosity base oil (AL).

[0042] Hereinafter, the high-viscosity base oil (AH), the low-viscosity base oil (AL), and the another base oil (AZ) will be described.

(High-viscosity Base Oil (AH))

[0043] The high-viscosity base oil (AH) contributes to improvement of wear resistance, fatigue life, and the like of the lubricating oil composition by maintaining the kinematic viscosity of the base oil (A) at a high level.

[0044] Here, the kinematic viscosity at 40°C (hereinafter, also referred to as a "kinematic viscosity at 40°C") of the high-viscosity base oil (AH) is preferably 1,000 mm²/s or more, more preferably 1,100 mm²/s or more, and still more preferably 1,200 mm²/s or more, from the viewpoint of more easily improving the wear resistance, the fatigue life, and the like of the lubricating oil composition. In addition, an upper limit value of the high-viscosity base oil (AH) is preferably 2,000 mm²/s. 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 1,000 mm²/s to 2,000 mm²/s, more preferably 1,100 mm²/s to 2,000 mm²/s, and still more preferably 1,200 mm²/s to 2,000 mm²/s.

[0045] The high-viscosity base oil (AH) is preferably a poly- α -olefin (hereinafter also referred to as a "PAO") from the viewpoint of increasing the viscosity index of the lubricating oil composition. Examples of the PAO include polybutene, polyisobutylene, 1-decene oligomer, an ethylene-propylene copolymer, and hydrides thereof.

[0046] The PAO may be used either alone or in combination of two or more thereof.

[0047] In addition, the high-viscosity base oil (AH) is more preferably a poly- α -olefin (hereinafter, also referred to as an "mPAO") obtained by using a metallocene catalyst as the PAO, from the viewpoint of further increasing the viscosity index of the lubricating oil composition.

[0048] The mPAO is preferably a poly- α -olefin or a hydride thereof obtained by production (polymerization) using, in presence of a metallocene catalyst, one type of an α -olefin having 8 to 12 carbon atoms alone or using two or more types of α -olefins in combination as a raw material.

[0049] The α -olefin having 8 to 12 carbon atoms as the raw material of the mPAO may be linear or branched, and is preferably a linear α -olefin. Examples thereof include 1-octene, 1-nonene, 1-decene, 1-undecene, and 1-dodecene. Preferably, examples of the raw material include a decene oligomer obtained by polymerization using 1-decene.

[0050] As the metallocene catalyst which is a polymerization catalyst used in the production of the mPAO, a complex having a conjugated carbon 5-membered ring containing a Group 4 element in the periodic table, that is, a combination of a metallocene complex and an oxygen-containing organic aluminum compound can be used.

[0051] As the Group 4 element in the periodic table in the metallocene complex, titanium, zirconium, and hafnium are used, and zirconium is preferred. In addition, as the complex having a conjugated carbon 5-membered ring, a complex having a substituted or unsubstituted cyclopentadienyl ligand is generally used.

[0052] Examples of a suitable metallocene complex include bis(n-octadecylcyclopentadienyl) zirconium dichloride, bis(trimethylsilylcyclopentadienyl) zirconium dichloride, bis(tetrahydroindenyl) zirconium dichloride, bis[(t-butyl)dimethylsilyl]cyclopentadienyl] zirconium dichloride, bis(di-t-butylcyclopentadienyl) zirconium dichloride, (ethylidene-bisindenyl) zirconium dichloride, biscyclopentadienyl zirconium dichloride, ethylidene bis(tetrahydroindenyl) zirconium dichloride, and bis[3,3-(2-methyl-benzindenyl)]dimethylsilanediy zirconium dichloride.

[0053] These may be used either alone or in combination of two or more thereof.

[0054] On the other hand, examples of the oxygen-containing organic aluminum compound include methylaluminumoxane, ethylaluminumoxane, and isobutylaluminumoxane. These may be used either alone or in combination of two or more thereof.

[0055] The mPAO has a viscosity index higher than that of a PAO produced by using a non-metallocene catalyst (Ziegler catalyst and the like), and thus has an effect of increasing the viscosity index of the lubricating oil composition.

[0056] The mPAO may be used either alone or in combination of two or more thereof.

[0057] A viscosity index of the high-viscosity base oil (AH) is preferably 100 or more, more preferably 150 or more, and still more preferably 170 or more. In addition, the viscosity index may be 300 or less, and may be 250 or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the viscosity index is preferably 100 to 300, more preferably 150 to 250, and still more preferably 170 to 250.

[0058] Here, the high-viscosity base oil (AH) preferably has a pour point of -20°C or lower. It is preferable that the pour point of the high-viscosity base oil (AH) is -20°C or lower because the lubricating oil composition containing the high-viscosity base oil (AH) has sufficient fluidity even in a low-temperature environment. The pour point of the high-viscosity base oil (AH) is more preferably -25°C or lower, and still more preferably -30°C or lower.

[0059] The kinematic viscosity and the viscosity index are values measured and calculated in conformity with JIS K

2283:2000, and the pour point is a value measured in conformity with JIS K 2269:1987.

[0060] In the lubricating oil composition according to the aspect of the present invention, a content of the high-viscosity base oil (AH) is preferably 35% by mass or more, more preferably 38% by mass or more, and still more preferably 40% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content of the high-viscosity base oil (AH) is preferably 75% by mass or less, more preferably 72% by mass or less, and still more preferably 70% 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 35% by mass to 75% by mass, more preferably 38% by mass to 72% by mass, and still more preferably 40% by mass to 70% by mass. When the content of the high-viscosity base oil (AH) is in the above range, the kinematic viscosity of the lubricating oil composition can be maintained high, and a lubricating oil composition having excellent wear resistance and fatigue life can be prepared.

[0061] The high-viscosity base oil (AH) may be used either alone or in combination of two or more thereof.

(Low-viscosity Base Oil (AL))

[0062] The low-viscosity base oil (AL) contributes to ensuring low-temperature properties of the lubricating oil composition.

[0063] Here, from the viewpoint of improving the low-temperature properties of the lubricating oil composition, the kinematic viscosity at 40°C of the low-viscosity base oil (AL) is preferably 5.0 mm²/s or more, more preferably 6.0 mm²/s or more, still more preferably 7.0 mm²/s or more, and yet still more preferably 8.0 mm²/s or more. In addition, the kinematic viscosity at 40°C is preferably 110 mm²/s or less, more preferably 90.0 mm²/s or less, still more preferably 80.0 mm²/s or less, and yet still more preferably 75 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 5.0 mm²/s to 110 mm²/s, more preferably 6.0 mm²/s to 90.0 mm²/s, still more preferably 7.0 mm²/s to 80.0 mm²/s, and yet still more preferably 8.0 mm²/s to 75.0 mm²/s.

[0064] Here, the low-viscosity base oil contributes to ensuring low-temperature properties of the lubricating oil composition, and has a flash point lower than that of the high-viscosity base oil, so that the flash point of the base oil as a whole is reduced, which causes a decrease in flash point of the lubricating oil composition. Therefore, as the low-viscosity base oil (AL), those having a high flash point among low-viscosity base oils are preferably used. From such a viewpoint, the low-viscosity base oil (AL) is preferably a low-viscosity poly- α -olefin (hereinafter, also referred to as a "PAO"), a mineral oil belonging to Group II or III in the American Petroleum Institute (API) base oil category, and a base oil in which a temperature gradient $\Delta|Dt|$ of a distillation temperature between two points, i.e., a distillation amount of 2.0 vol% and a distillation amount of 5.0 vol%, in a distillation curve is 6.8°C/vol% or less (preferably a base oil in which a saturated content in a clay gel method measured in conformity with ASTM D-2007 is 90% by mass or more, a sulfur content measured in conformity with ASTM D1552 is 0.03% by mass or less, and a viscosity index obtained in conformity with ASTM D2270 is 120 or more). A PAO having a low viscosity among the PAOs can be used.

[0065] In the base oil in which a temperature gradient $\Delta|Dt|$ of a distillation temperature between two points, i.e., a distillation amount of 2.0 vol% and a distillation amount of 5.0 vol% in a distillation curve is 6.8°C/vol% or less, the temperature gradient $\Delta|Dt|$ is preferably 6.5°C/vol% or less, more preferably 6.3°C/vol% or less, still more preferably 6.0°C/vol% or less, and yet still more preferably 5.0°C/vol% or less.

[0066] The temperature gradient $\Delta|Dt|$ is usually 0.1°C/vol% or more.

[0067] The distillation temperature at which the distillation amount is 2.0 vol% in the distillation curve is preferably 405°C to 510°C, more preferably 410°C to 500°C, still more preferably 415°C to 490°C, and yet still more preferably 430°C to 480°C.

[0068] The distillation temperature at which the distillation amount is 5.0 vol% in the distillation curve is preferably 425°C to 550°C, more preferably 430°C to 520°C, still more preferably 434°C to 500°C, and yet still more preferably 450°C to 490°C.

[0069] Aparaffin content (%C_P) in the base oil, in which the temperature gradient $\Delta|Dt|$ of the distillation temperature between two points, i.e., a distillation amount of 2.0 vol% and a distillation amount of 5.0 vol%, in the distillation curve is 6.8°C/vol% or less, is usually 50 or more, preferably 55 or more, more preferably 60 or more, still more preferably 65 or more, yet still more preferably 70 or more, and even yet still more preferably 80 or more, and is usually 99 or less.

[0070] In the present description, the paraffin content (%C_P) means a value measured in conformity with ASTM D-3238 ring analysis (n-d-M method).

[0071] The viscosity index of the low-viscosity base oil (AL) is preferably 80 or more, more preferably 90 or more, still more preferably 100 or more, yet still more preferably 110 or more, and even yet still more preferably 120 or more, and the upper limit value thereof is not particularly limited, and is, for example, 200.

[0072] In the lubricating oil composition according to the aspect of the present invention, the content of the low-viscosity base oil (AL) is preferably 10% by mass or more, more preferably 15% by mass or more, and still more preferably 20% by mass or more, based on the total amount of the lubricating oil composition, from the viewpoints of easily ensuring

the low-temperature properties of the lubricating oil composition and preventing a decrease in flash point of the lubricating oil composition. In addition, the content of the low-viscosity base oil (AL) is preferably 60% by mass or less, more preferably 55% by mass or less, and still more preferably 50% 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 10% by mass to 60% by mass, more preferably 15% by mass to 55% by mass, and still more preferably 20% by mass to 50% by mass.

(Another Base Oil (AZ))

[0073] The another base oil (AZ) is not particularly limited, and examples thereof include various base oils which do not correspond to the high-viscosity base oil (AH) and the low-viscosity base oil (AL). From the viewpoint of improving a detergency dispersion effect and thermal stability, and the like, an ester-based oil is preferred.

[0074] As the ester-based oil, a polyol ester is preferably used. The polyol ester may be either a partial ester of a polyol or a complete ester of a polyol, and it is preferable to use a partial ester of a polyol from the viewpoint of sludge solubility.

[0075] The polyol serving as a raw material of the polyol ester is not particularly limited, and is preferably an aliphatic polyol. Examples of the polyol can include: dihydric alcohols such as ethylene glycol, diethylene glycol, triethylene glycol, propylene glycol, trimethylene glycol, tetramethylene glycol, and neopentyl glycol; trihydric alcohols such as glycerin, trimethylolpropane, and trimethylolpropane; and tetrahydric or higher polyhydric alcohols such as diglycerin, triglycerin, pentaerythritol, dipentaerythritol, mannitol, and sorbitol.

[0076] A hydrocarbonyl group constituting the polyol ester is preferably an alkyl group or an alkenyl group having 6 to 30 carbon atoms, and more preferably an alkyl group or an alkenyl group having 12 to 24 carbon atoms. Examples thereof include various groups such as a hexyl group, an octyl group, a decyl group, a dodecyl group, a tetradecyl group, a hexadecyl group, a heptadecyl group, an octadecyl group, a hexenyl group, an octenyl group, a decenyl group, a dodecenyl group, a tetradecenyl group, a hexadecenyl group, and an octadecenyl group.

[0077] The alkyl group and the alkenyl group may be linear or branched.

[0078] Specific examples of the complete ester of the polyol can include, but are not limited to, neopentyl glycol dilaurate, neopentyl glycol dimyristate, neopentyl glycol dipalmitate, neopentyl glycol distearate, neopentyl glycol diisostearate, trimethylolpropane trilaurate, trimethylolpropane trimyristate, trimethylolpropane tripalmitate, trimethylolpropane tristearate, trimethylolpropane triisostearate, glycerin trilaurate, glycerin tristearate, and glycerin triisostearate.

[0079] The partial ester of the polyol is not particularly limited as long as at least one hydroxy group remains.

[0080] Specific examples of the partial ester of the polyol include, but are not limited to, neopentyl glycol monolaurate, neopentyl glycol monomyristate, neopentyl glycol monopalmitate, neopentyl glycol monostearate, neopentyl glycol monoisostearate, trimethylolpropane mono (or di) laurate, trimethylolpropane mono (or di) myristate, trimethylolpropane mono (or di) palmitate, trimethylolpropane mono (or di) stearate, trimethylolpropane mono (or di) isostearate, glycerin mono (or di) laurate, glycerin mono (or di) stearate, and glycerin mono (or di) isostearate, and preferably trimethylolpropane mono (or di) isostearate.

[0081] In the lubricating oil composition according to the aspect of the present invention, a content of the another base oil (AZ) is preferably 6% by mass or more based on the total amount of the lubricating oil composition, from the viewpoint of further improving the sludge solubility. In addition, the content of the another base oil (AZ) is preferably 15% by mass or less, more preferably 13% by mass or less, and still more preferably 11% by mass or less. Upper limit values and lower limit value of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 6% by mass to 15% by mass, more preferably 6% by mass to 13% by mass, and still more preferably 6% by mass to 11% by mass.

[0082] The another base oil (AZ) may be used either alone or in combination of two or more thereof.

[0083] In the lubricating oil composition according to the aspect of the present invention, the content of the base oil (A) is preferably 75% by mass or more, more preferably 78% by mass or more, and still more preferably 80% by mass or more, based on the total amount of the lubricating oil composition. In addition, the content of the base oil (A) is preferably 99.9% by mass or less. Upper limit value and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content is preferably 75% by mass to 99.9% by mass, more preferably 78% by mass to 99.9% by mass, and still more preferably 80% by mass to 99.9% by mass.

[0084] In addition, in the lubricating oil composition according to the aspect of the present invention, when the base oil (A) contains the high-viscosity base oil (AH) and the low-viscosity base oil (AL), the total content of the high-viscosity base oil (AH) and the low-viscosity base oil (AL) is preferably 75% by mass to 100% by mass, more preferably 78% by mass to 100% by mass, and still more preferably 80% by mass to 100% by mass, based on the total amount of the base oil (A).

[0085] In the lubricating oil composition according to the aspect of the present invention, when the base oil (A) contains the high-viscosity base oil (AH) and the low-viscosity base oil (AL), a content ratio [(AH)/(AL)] of the high-viscosity base oil (AH) to the low-viscosity base oil (AL) is preferably 50/50 or more in terms of a mass ratio. In addition, the content

ratio [(AH)/(AL)] is preferably 80/20 or less, more preferably 75/25 or less, and still more preferably 60/30 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 80/20 to 50/50, more preferably 75/25 to 50/50, and still more preferably 60/30 to 50/50.

[0086] In addition, in the lubricating oil composition according to the aspect of the present invention, when the base oil (A) includes the another base oil (AZ), a ratio $\{[(AH) + (AL)]/(AZ)\}$ of the total content of the high-viscosity base oil (AH) and the low-viscosity base oil (AL) to the content of the another base oil (AZ) 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 ratio $\{[(AH) + (AL)]/(AZ)\}$ 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 ratio $\{[(AH) + (AL)]/(AZ)\}$ 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.

<Silicone-based Anti-foaming Agent (B)>

[0087] The lubricating oil composition of the present invention contains the silicone-based anti-foaming agent (B).

[0088] In the present invention, it is possible to achieve both long-term anti-foaming performance and detergency by significantly reducing the content of the silicone-based anti-foaming agent (B) to be smaller than the content of the silicone-based anti-foaming agent (B) in the lubricating oil composition in the related art. That is, even if the lubricating oil composition of the present invention contains the silicone-based anti-foaming agent (B), the content of the silicone-based anti-foaming agent (B) is overwhelmingly smaller than that in the lubricating oil composition in the related art.

[0089] Specifically, in the lubricating oil composition of the present invention, the silicon atom content is adjusted to 50 ppb by mass to 4,000 ppb by mass based on the total amount of the lubricating oil composition. The silicone-based anti-foaming agent (B) is added such that the silicon atom content in the lubricating oil composition satisfies the numerical range.

[0090] In other words, in the lubricating oil composition of the present invention, the silicone-based anti-foaming agent (B) is added in a content of 50 ppb by mass to 4,000 ppb by mass in terms of silicon atoms.

[0091] In the lubricating oil composition according to the aspect of the present invention, from the viewpoint of facilitating the exhibition of the effects of the present invention, the content of the silicone-based anti-foaming agent (B) in terms of silicon atoms is preferably 100 ppb by mass or more, more preferably 200 ppb by mass or more, still more preferably 250 ppb by mass or more, yet still more preferably 300 ppb by mass or more, even yet still more preferably 350 ppb by mass or more, further preferably 400 ppb by mass or more, still further preferably 450 ppb by mass or more, and yet still further preferably 500 ppb by mass or more, based on the total amount of the lubricating oil composition. In addition, the silicone-based anti-foaming agent (B) is also added in a content of preferably 3,500 ppb by mass or less, more preferably 3,000 ppb by mass or less, still more preferably 2,500 ppb by mass or less, yet still more preferably 2,200 ppb by mass or less, even yet still more preferably 2,000 ppb by mass or less, further preferably 1,800 ppb by mass or less, still further preferably 1,600 ppb by mass or less, and yet still further preferably 1,500 ppb by mass or less.

[0092] Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the content of the silicone-based anti-foaming agent (B) is preferably 100 ppb by mass to 3,500 ppb by mass, more preferably 200 ppb by mass to 3,000 ppb by mass, still more preferably 250 ppb by mass to 2,500 ppb by mass, yet still more preferably 300 ppb by mass to 2,200 ppb by mass, even yet still more preferably 350 ppb by mass to 2,000 ppb by mass, further preferably 400 ppb by mass to 1,800 ppb by mass, still further preferably 450 ppb by mass to 1,600 ppb by mass, and yet still further preferably 500 ppb by mass to 1,500 ppb by mass.

[0093] In the lubricating oil composition according to the aspect of the present invention, the active component contained in the silicone-based anti-foaming agent (B) is not particularly limited as long as the active component is a polymer containing silicon atoms and exhibiting anti-foaming performance. Examples of such a polymer include polydimethylsiloxane and fluorinated polysiloxane.

[0094] These may be used either alone or in combination of two or more thereof.

[0095] The silicone-based anti-foaming agent (B) is preferably added to the base oil (A) in the form of a solution (dispersion) by adding a diluent oil and the like in consideration of handleability, and solubility and dispersibility in the base oil (A), and is preferably uniformly dissolved and dispersed by stirring.

<Lubricating Oil Additive>

[0096] The lubricating oil composition according to the aspect of the present invention may contain other additives (hereinafter, also referred to as a "lubricating oil additive") other than the silicone-based anti-foaming agent (B) as long as the effects of the present invention are not impaired.

[0097] Examples of the lubricating oil additive include an antioxidant, an extreme pressure agent, an anti-emulsifier, a rust inhibitor, a viscosity index improver, a pour point depressant, a metal deactivator, an ash-free detergent dispersant, and a friction modifier.

[0098] These lubricating oil additives may be used either alone or in combination of two or more thereof.

[0099] In the present description, an additive such as a viscosity index improver may be blended with other components in the form of a solution dissolved in a diluent oil in consideration of handleability and solubility in the base oil. In such a case, in the present description, the content of the additive such as the viscosity index improver is a content in terms of an active component (resin content) excluding the diluent oil.

[0100] Hereinafter, details of each of the above lubricating oil additives will be described.

(Antioxidant)

[0101] An amine-based antioxidant, a phenol-based antioxidant, a phosphorus-based antioxidant, a sulfur-based antioxidant, and a molybdenum amine complex-based antioxidant, all of which are employed in the lubricating oil composition in the related art, can be used as the antioxidant. These antioxidants may be used either alone or in combination of two or more thereof.

[0102] Examples of the amine-based antioxidant include: monoalkyl diphenylamine compounds such as mono-octyl diphenylamine and monononyl diphenylamine; dialkyl diphenylamine compounds such as 4,4'-dibutyl diphenylamine, 4,4'-dipentyl diphenylamine, 4,4'-di-hexyl diphenylamine, 4,4'-diheptyl diphenylamine, 4,4'-dioctyl diphenylamine, 4,4'-dinonyl diphenylamine, monobutylphenylmono-octyl phenylamine; polyalkyl diphenylamine compounds such as tetrabutyl diphenylamine, tetrahexyl diphenylamine, tetraoctyl diphenylamine, and tetranonyl diphenylamine; and naphthylamine compounds such as α -naphthylamine, phenyl- α -naphthylamine, butylphenyl- α -naphthylamine, pentylphenyl- α -naphthylamine, hexylphenyl- α -naphthylamine, heptylphenyl- α -naphthylamine, octylphenyl- α -naphthylamine, and nonylphenyl- α -naphthylamine.

[0103] Examples of the phenol-based antioxidant include monophenol compounds such as 2,6-di-tert-butyl-4-methylphenol, 2,6-di-tert-butyl-4-ethylphenol, and octadecyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate; and diphenol compounds such as 4,4'-methylenebis(2,6-di-tert-butylphenol) and 2,2'-methylenebis(4-ethyl-6-tert-butylphenol).

[0104] Examples of the phosphorus-based antioxidant include triphenyl phosphite.

[0105] Examples of the sulfur-based antioxidant include a thiopentene compound such as 2,6-di-tert-butyl-4-(4,6-bis(octylthio)-1,3,5-triazine-2-ylamino)phenol, and a reaction product of phosphorus pentasulfide and pinene.

[0106] As the molybdenum amine complex-based antioxidant, a hexavalent molybdenum compound, specifically, a compound obtained through a reaction between molybdenum trioxide and/or molybdic acid and an amine compound can be used.

[0107] A content of the antioxidant may be a minimum amount necessary for maintaining oxidation stability, and is preferably 0.01% by mass to 1.5% by mass, and more preferably 0.1% by mass to 1% by mass, based on the total amount of the lubricating oil composition.

(Extreme Pressure Agent)

[0108] An organic metal-based extreme pressure agent, a sulfur-based extreme pressure agent, a phosphorous-based extreme pressure agent, and a sulfur-phosphorus-based extreme pressure agent, all of which are used in the lubricating oil composition in the related art, can be used as the extreme pressure agent. These extreme pressure agents may be used either alone or in combination of two or more thereof.

[0109] Examples of the organic metal-based extreme pressure agent include organic molybdenum compounds such as molybdenum dialkyldithiocarbamate (MoDTC) and molybdenum dialkyldithiophosphate (MoDTP), and organic zinc compounds such as zinc dialkyldithiocarbamate (ZnDTC) and zinc dialkyldithiophosphate (ZnDTP).

[0110] Examples of the sulfur-based extreme pressure agent include at least one of a sulfurized fat and a sulfurized fatty oil, a sulfurized fatty acid, a sulfurized ester, a sulfurized olefin, a monosulfide, a polysulfide, a dihydrocarbyl sulfide, a thiadiazole compound, an alkylthiocarbamoyl compound, a thiocarbamate compound, a thiopentene compound, and a dialkyl thiodipropionate compound.

[0111] Examples of the phosphorous-based extreme pressure agent include: phosphoric acid esters such as an aryl phosphate, an alkyl phosphate, an alkenyl phosphate, and an alkylaryl phosphate; acidic phosphoric acid esters such as a monoaryl acid phosphate, a diaryl acid phosphate, a monoalkyl acid phosphate, a dialkyl acid phosphate, a monoalkenyl acid phosphate, and a dialkenyl acid phosphate; phosphite esters such as an aryl hydrogen phosphite, an alkyl hydrogen phosphite, an aryl phosphite, an alkyl phosphite, an alkenyl phosphite, and an aryl alkyl phosphite; acidic phosphite esters such as a monoalkyl acid phosphite, a dialkyl acid phosphite, a monoalkenyl acid phosphite, and a dialkenyl acid phosphite; and an amine salt thereof.

[0112] Examples of the sulfur-phosphorus-based extreme pressure agent include a monoalkyl thiophosphate, a dialkyl dithiophosphate, a trialkyl trithiophosphate, an amine salt thereof, and zinc dialkyl dithiophosphate (Zn-DTP).

[0113] A content of the extreme pressure agent is preferably 0.1% by mass to 10% by mass, more preferably 0.5% by mass to 8.0% by mass, and still more preferably 1.0% by mass to 6.0% by mass, based on the total amount of the

lubricating oil composition, from the viewpoint of an addition effect.

(Anti-emulsifier)

[0114] Examples of the anti-emulsifier include: cationic surfactants such as a quaternary ammonium salt and imidazoline; polyoxyalkylene block polymers (such as an ethylene oxide (EO)-propylene oxide (PO) block copolymer), polyoxyalkylene glycols, and polyoxyalkylene polyglycols; and an alkylene oxide adduct of an alkylphenol-formaldehyde polycondensate.

[0115] A content of the anti-emulsifier is preferably 0.001% by mass to 0.5% by mass, and more preferably 0.002% by mass to 0.2% by mass, based on the total amount of the lubricating oil composition.

(Rust Inhibitor)

[0116] Examples of the rust inhibitor include a metal sulfonate, an alkylbenzene sulfonate, a dinonylnaphthalene sulfonate, an organic phosphite ester, an organic phosphoric acid ester, an organic sulfonic acid metal salt, an organic phosphoric acid metal salt, an alkenyl succinic acid ester, a polyhydric alcohol ester, and a benzotriazole-based compound.

[0117] A content of the rust inhibitor is preferably 0.01% by mass to 10.0% by mass, and more preferably 0.05% by mass to 5.0% by mass, based on the total amount of the lubricating oil composition.

(Viscosity Index Improver)

[0118] Examples of the viscosity index improver include a polymethacrylate (PMA), a dispersion type polymethacrylate, an olefin-based copolymer (an olefin copolymer (OCP), for example, an ethylene-propylene copolymer), a dispersion type olefin-based copolymer, and a styrene-based copolymer (for example, a styrene-diene hydrogenated copolymer).

[0119] An addition amount of the viscosity index improver is preferably 1% by mass to 10% by mass, and more preferably 2% by mass to 8% by mass, based on the total amount of the lubricating oil composition, from the viewpoint of an addition effect.

[0120] In addition, in the lubricating oil composition according to the aspect of the present invention, the viscosity index improver preferably contains at least an olefin copolymer, and a content of the olefin copolymer is preferably 1% by mass to 10% by mass, and more preferably 2% by mass to 8% by mass, based on the total amount of the lubricating oil composition.

(Pour Point Depressant)

[0121] Examples of the pour point depressant include an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and naphthalene, a condensate of chlorinated paraffin and phenol, and a polymer such as a polymethacrylate and a polyalkylstyrene. A weight average molecular weight (Mw) of these polymers is preferably 50,000 to 150,000.

[0122] A content of the pour point depressant is preferably 0.01% by mass to 5.0% by mass, and more preferably 0.02% by mass to 2.0% by mass, based on the total amount of the lubricating oil composition, from the viewpoint of an addition effect.

(Metal Deactivator)

[0123] 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.

[0124] A content of the metal deactivator is preferably 0.01% by mass to 5.0% by mass, and more preferably 0.02% by mass to 3.0% by mass, based on the total amount of the lubricating oil composition, from the viewpoint of an addition effect.

(Ash-free Detergent Dispersant)

[0125] Examples of the ash-free detergent dispersant include a succinimide, a boron-containing succinimide, a benzylamine, a boron-containing benzylamine, a succinate ester, and a mono- or di-carboxylic acid amide represented by fatty acids or succinic acids.

[0126] A content of the ash-free detergent dispersant is preferably 0.01% by mass to 5.0% by mass, and more preferably 0.02% by mass to 3.0% by mass, based on the total amount of the lubricating oil composition, from the viewpoint of an addition effect.

(Friction Modifier)

[0127] Examples of the friction modifier include ash-free friction modifiers such as an aliphatic amine, an aliphatic alcohol, and an aliphatic ether, which have at least one alkyl group or alkenyl group having 6 to 30 carbon atoms in a molecule.

[0128] A content of the friction modifier is preferably 0.01% by mass to 5.0% by mass based on the total amount of the lubricating oil composition.

[Physical Properties of Lubricating Oil Composition]

<Silicon Atom Content>

[0129] In the lubricating oil composition according to the present invention, the silicon atom content is 50 ppb by mass to 4,000 ppb by mass based on the total amount of the lubricating oil composition.

[0130] When the silicon atom content is less than 50 ppb by mass, the long-term anti-foaming performance cannot be ensured. In addition, when the silicon atom content is more than 4,000 ppb by mass, the detergency cannot be ensured.

[0131] Here, in the lubricating oil composition according to the aspect of the present invention, from the viewpoint of facilitating the exhibition of the effects of the present invention, the silicon atom content is preferably 100 ppb by mass or more, more preferably 200 ppb by mass or more, still more preferably 250 ppb by mass or more, yet still more preferably 300 ppb by mass or more, even yet still more preferably 350 ppb by mass or more, further preferably 400 ppb by mass or more, still further preferably 450 ppb by mass or more, and yet still further preferably 500 ppb by mass or more, based on the total amount of the lubricating oil composition. In addition, the silicon atom content is preferably 3,500 ppb by mass or less, more preferably 3,000 ppb by mass or less, still more preferably 2,500 ppb by mass or less, yet still more preferably 2,200 ppb by mass or less, even yet still more preferably 2,000 ppb by mass or less, further preferably 1,800 ppb by mass or less, still further preferably 1,600 ppb by mass or less, and yet still further preferably 1,500 ppb by mass or less. Upper limit values and lower limit values of these numerical ranges can be freely combined as desired. Specifically, the silicon atom content is preferably 100 ppb by mass to 3,500 ppb by mass, more preferably 200 ppb by mass to 3,000 ppb by mass, still more preferably 250 ppb by mass to 2,500 ppb by mass, yet still more preferably 300 ppb by mass to 2,200 ppb by mass, even yet still more preferably 350 ppb by mass to 2,000 ppb by mass, further preferably 400 ppb by mass to 1,800 ppb by mass, still further preferably 450 ppb by mass to 1,600 ppb by mass, and yet still further preferably 500 ppb by mass to 1,500 ppb by mass.

[0132] The silicon atom content in the lubricating oil composition can be measured by an inductively coupled plasma emission spectrometer (ICP). In addition, when there is no silicon atom other than the silicon atoms derived from the silicone-based anti-foaming agent (B) in the lubricating oil composition, the silicon atom content in the lubricating oil composition can be theoretically calculated based on the content of the silicone-based anti-foaming agent (B) (in terms of solid content) and the content of the silicon atoms contained in the silicone-based anti-foaming agent (B).

<Kinematic Viscosity and Viscosity Index>

[0133] The kinematic viscosity at 40°C of the lubricating oil composition according to the aspect of the present invention is preferably 10 mm²/s to 500 mm²/s, more preferably 30 mm²/s to 450 mm²/s, and still more preferably 50 mm²/s to 400 mm²/s.

[0134] The viscosity index of the lubricating oil composition according to the aspect of the present invention is preferably 100 or more, more preferably 110 or more, and still more preferably 120 or more.

[0135] In the present description, the kinematic viscosity at 40°C and the viscosity index mean values measured and calculated in conformity with JIS K2283:2000.

[Method of Producing Lubricating Oil Composition]

[0136] A method of producing the lubricating oil composition of the present invention is not particularly limited.

[0137] For example, the method of producing the lubricating oil composition of the aspect of the present invention is a method of producing the lubricating oil composition including a step of mixing the base oil (A) and the silicone-based anti-foaming agent (B), in which the silicon atom content is adjusted to 50 ppb by mass to 4,000 ppb by mass based on the total amount of the lubricating oil composition.

[0138] A method of mixing the above components is not particularly limited, and examples of the method include a method including a step of blending the silicone-based anti-foaming agent (B) into the base oil (A). Other additives (lubricating oil additive) other than the silicone-based anti-foaming agent (B) may be added simultaneously with the silicone-based anti-foaming agent (B), or may be separately added. The silicone-based anti-foaming agent (B) and other

additives (lubricating oil additive) may be added in the form of a solution (dispersion) by adding a diluent oil and the like. After the components are blended, it is preferable to stir and uniformly disperse the components by a known method.

[Use of Lubricating Oil Composition]

[0139] The lubricating oil composition of the present invention is a lubricating oil composition excellent in both long-term anti-foaming performance and detergency. Therefore, the lubricating oil composition can be widely used for lubrication uses in which long-term anti-foaming performance and detergency are required.

[0140] For example, the lubricating oil composition can be suitably used as an accelerator oil for a wind turbine, a hydraulic oil, a compressor oil, a gear oil, a cutting oil, a machine tool oil, a refrigerator oil, a turbine oil, an internal combustion engine oil, a transmission oil, or an axle unit oil for a vehicle.

[0141] Therefore, in the aspect of the present invention, the following method is provided.

[0142] In the use method, the lubricating oil composition of the present invention is used as an accelerator oil for a wind turbine, a hydraulic oil, a compressor oil, a gear oil, a cutting oil, a machine tool oil, a refrigerator oil, a turbine oil, an internal combustion engine oil, a transmission oil, or an axle unit oil for a vehicle.

[Provided One Aspect of Present Invention]

[0143] In an aspect of the present invention, the following [1] to [8] are provided.

[1] A lubricating oil composition containing:

a base oil (A); and

a silicone-based anti-foaming agent (B), in which

a silicon atom content is 50 ppb by mass to 4,000 ppb by mass based on a total amount of the lubricating oil composition.

[2] The lubricating oil composition according to [1], in which

the base oil (A) is one or more selected from the group consisting of a synthetic oil (A1) and a mineral oil (A2).

[3] The lubricating oil composition according to [1], in which

the base oil (A) is two or more selected from the group consisting of a synthetic oil (A1) and a mineral oil (A2).

[4] The lubricating oil composition according to [1], in which

the base oil (A) is two or more selected from the group consisting of a synthetic oil (A1) and a mineral oil (A2) and having different kinematic viscosities at 40°C.

[5] The lubricating oil composition according to any one of [1] to [4], in which

a total content of the base oil (A) and the silicone-based anti-foaming agent (B) is 75% by mass or more and 94.9% by mass or less based on the total amount of the lubricating oil composition.

[6] The lubricating oil composition according to any one of [1] to [5], in which

the silicone-based anti-foaming agent (B) comprises one or more selected from the group consisting of polydimethylsiloxane and fluorinated polysiloxane.

[7] The lubricating oil composition according to any one of [1] to [6], further containing:

one or more lubricating oil additives selected from the group consisting of an antioxidant, an extreme pressure agent, an anti-emulsifier, a rust inhibitor, a viscosity index improver, a pour point depressant, a metal deactivator, an ash-free detergent dispersant, and a friction modifier.

[8] The lubricating oil composition according to any one of [1] to [7], which is used as an accelerator oil for a wind turbine, a hydraulic oil, a compressor oil, a gear oil, a cutting oil, a machine tool oil, a refrigerator oil, a turbine oil, an internal combustion engine oil, a transmission oil, or an axle unit oil for a vehicle.

[Examples]

[0144] The present invention will be described in detail with reference to the following Examples, but the present invention is not limited to the following Examples.

[Method of Measuring Various Physical Property Values]

(1) Kinematic viscosity and viscosity index of base oil and lubricating oil composition

[0145] The kinematic viscosity and the viscosity index were measured and calculated in conformity with JIS

K2283:2000.

(2) Paraffin content (%Cp)

5 **[0146]** The paraffin content was measured in conformity with ASTM D-3238 ring analysis (n-d-M method).

[Examples 1 to 4 and Comparative Examples 1 to 4]

10 **[0147]** The following base oil (A) and silicone-based anti-foaming agent (B) were sufficiently mixed in a blending amount (% by mass) shown in Table 1 to prepare lubricating oil compositions in Examples 1 to 3 and Comparative Examples 1 and 2.

[0148] In addition, the following base oil (A), silicone-based anti-foaming agent (B), and lubricating oil additive were sufficiently mixed in a blending amount (% by mass) shown in Table 2 to prepare lubricating oil compositions in Example 4 and Comparative Examples 3 and 4.

15 <Base Oil (A)>

(High-viscosity Base Oil (AH))

20 **[0149]**

- High-viscosity base oil (AH)-1: poly- α -olefin (PAO), kinematic viscosity at 40°C = 1,240 mm²/s, and viscosity index = 170
- High-viscosity base oil (AH)-2: decene oligomer (mPAO) obtained by polymerizing 1-decene using metallocene catalyst, kinematic viscosity at 40°C = 1,616 mm²/s, and viscosity index = 202

(Low-viscosity Base Oil (AL))

30 **[0150]**

- Low-viscosity base oil (AL)-1: poly- α -olefin (PAO) mainly composed of C40, kinematic viscosity at 40°C = 28.8 mm²/s, and viscosity index = 136
- Low-viscosity base oil (AL)-2: mineral oil classified into Group II in API classification, kinematic viscosity at 40°C = 30.6 mm²/s, and viscosity index = 104
- Low-viscosity base oil (AL)-3: base oil in which saturated content in clay gel method measured in conformity with ASTM D-2007 is 90% by mass or more, sulfur content measured in conformity with ASTM D1552 is 0.03% by mass or less, and viscosity index obtained in conformity with ASTM D2270 is 120 or more, kinematic viscosity at 40°C = 43.75 mm²/s, viscosity index = 143, and paraffin content (%Cp) = 94.1

40 **[0151]** The low-viscosity base oil (AL)-3 is a base oil prepared by the following method.

<Production Method>

45 **[0152]** A feedstock oil, which was a fraction oil of 200 neutral or more, was subjected to a hydrogenation isomerization dewaxing treatment, then subjected to a hydrofinishing treatment, and was thereafter distilled at a distillation temperature at which a 5 vol% fraction of a distillation curve was 460°C or higher, and fractions having a kinematic viscosity at 40°C of 19.8 mm²/s to 50.6 mm²/s were collected, so as to prepare the low-viscosity base oil (AL)-3.

[0153] Conditions for the hydrogenation isomerization dewaxing treatment are as follows.

- 50 • Hydrogen gas supply proportion: 300 Nm³ to 400 Nm³ per kiloliter of feedstock oil to be supplied
- Hydrogen partial pressure: 10 MPa to 15 MPa
- Liquid hourly space velocity (LHSV): 0.5 hr⁻¹ to 1.0 hr⁻¹
- Reaction temperature: 300°C to 350°C

55 **[0154]** Various properties of the obtained low-viscosity base oil (AL)-3 were as follows.

- Distillation temperature at distillation amount of 2.0 vol%: 451.0°C
- Distillation temperature at distillation amount of 5.0 vol%: 464.0°C

- Temperature gradient $\Delta|Dt| = 4.3^{\circ}\text{C}/\text{vol}\%$

[0155] The distillation temperatures at the distillation amounts of 2.0 vol% and 5.0 vol% were measured by distillation gas chromatography in conformity with ASTM D6352.

(Another Base Oil (AZ))

[0156]

- Ester-based oil: ester of trimethylolpropane and isostearic acid (molar ratio: 1:2), kinematic viscosity at $40^{\circ}\text{C} = 106.7 \text{ mm}^2/\text{s}$, viscosity index = 124

<Silicone-based Anti-foaming Agent (B)>

[0157] A silicone-based anti-foaming agent having an active component concentration of 0.2% by mass was used.

[0158] The active component is polydimethylsiloxane, and a silicon atom content of the polydimethylsiloxane is 0.081 % by mass based on a total amount of the silicone-based anti-foaming agent.

[0159] The silicone-based anti-foaming agent (B) was diluted with a light oil to prepare a diluted product, and then blended with the base oil (A). Table 1 and Table 2 show the content of the silicone-based anti-foaming agent (B) in the diluted product of the silicone-based anti-foaming agent (B) (based on a total amount of the lubricating oil composition) and a content of the light oil used for the dilution of the silicone-based anti-foaming agent (B) (based on the total amount of the lubricating oil composition).

<Lubricating Oil Additive>

[0160]

- Phenol-based antioxidant: octadecyl-3-(3,5-di-*t*-butyl-4-hydroxyphenyl)propionate.
- Amine-based antioxidant: monobutyl phenyl mono-octylphenylamine.
- Dihydrocarbyl sulfide: mixture of di-*tert*-butyl disulfide and di-*tert*-butyl trisulfide, S content = 38.5%.
- Alkylthiophosphoric acid ester: tris[2,4-isoalkyl(C_9 , C_{10})phenyl] thiophosphate.
- Alkyl thiocarbamate: methylenebis(dibutyl dithiocarbamate), S content = 30.3%.
- Alkylbenzotriazole: N-dialkylaminomethyl benzotriazole (N = 14.6%).
- Acidic phosphoric acid ester: isodecyl acid phosphate.
- Alkylamine: trioctylamine.
- EO-PO copolymer: xylene solution of EO-PO block copolymer (10%)
- Alkenyl succinimide: mixture of 50% polybutenyl succinimide, 20% polybutene, and 30% mineral oil (base number: 37 mg KOH/g).
- OCP: ethylene propylene oligomer.

[Evaluation]

[0161] The prepared lubricating oil compositions were subjected to the following tests.

<Evaluation of Foaming>

[0162] By a method in conformity with JIS K 2518:2003, air blowing was started at 60°C , and a volume of foams was measured after one day (after 1,440 minutes) and after 2 days (after 2,880 minutes).

[0163] In the foaming test, the foaming having a foaming amount of 50 mL or less both after 1,440 minutes and 2,880 minutes was regarded as passed (A), and the foaming having a foaming amount of more than 50 mL after 1440 minutes or 2,880 minutes was regarded as failed (F).

<Evaluation of Detergency>

[0164] The detergency of the lubricating oil composition was evaluated using a pollution degree code according to ISO 4406:1999.

[0165] Specifically, the sampled lubricating oil composition was measured by a particle counter to obtain a pollution degree code. In the pollution degree code, the number of particles of the sampled lubricating oil composition was divided

EP 4 130 212 A1

into particle size ranges of 4 µm or more, 6 µm or more, and 14 µm or more, and scale numbers (0 to 28) allocated from the number of particles in 1 mL were divided by diagonal lines (/), and the "scale number for number of particles (in 1 mL) of 4 µm or more"/"scale number for number of particles (in 1 mL) of 6 µm or more"/"scale number for number of particles (in 1 mL) of 14 µm or more" was obtained. A larger pollution degree code indicates a larger number of particles and lower detergency.

[0166] In the present Examples, a lubricating oil composition in which the "scale number for number of particles (in 1 mL) of 6 µm or more" was 15 or less (the number of particles: 320 counts/1 mL or less) and the "scale number for number of particles (in 1 mL) of 14 µm or more" was 12 or less (the number of particles: 40 counts/1 mL or less) was regarded as passed (A).

[0167] In addition, a lubricating oil composition in which the "scale number for number of particles (in 1 mL) of 6 µm or more" was 16 or more (the number of particles: more than 320 counts/1 mL) or the "scale number for number of particles (in 1 mL) of 14 µm or more" was 13 or more (the number of particles: more than 40 counts/1 mL) was regarded as failed (F).

[0168] The evaluation results are shown in Tables 1 and 2.

[0169] The "content of silicon atoms in lubricating oil composition" in Tables 1 and 2 is a value obtained by calculation based on the silicon atom content in the silicone-based anti-foaming agent (B).

EP 4 130 212 A1

Table 1

			Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2
Lubricating oil composition	Base oil (A) (unit: % by mass)	High- viscosity base oil (AH)-1	63.28	61.37	-	63.28	63.28
		High- viscosity base oil (AH)-2	-	-	61.37	-	-
		Low- viscosity base oil (AL)-1	36.62	-	-	36.62	36.62
		Low- viscosity base oil (AL)-2	-	38.53	-	-	-
		Low- viscosity base oil (AL)-3	-	-	38.53	-	-
		Another base oil (AZ)	-	-	-	-	-
	Diluted product of silicone- based anti- foaming agent (B) (unit: % by mass)	Light oil	0.0998	0.0998	0.0998	0.09999	0.099
		Silicone- based anti- foaming agent (B)	0.0002	0.0002	0.0002	0.00001	0.001
	Total (unit: % by mass)		100	100	100	100	100
	VG		320	320	320	320	320
	Silicon atom content in lubricating oil composition (theoretical value, unit: ppb by mass)		810	810	810	40	4049

EP 4 130 212 A1

(continued)

			Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2
Evaluation	Evaluation of foaming property	Foaming amount after 1,440 minutes (mL)	0	0	0	410	0
		Foaming amount after 2,880 minutes (mL)	0	0	0	410	0
		Evaluation	A	A	A	F	A
	Evaluation of detergency	4 μm	2,305	1,850	1,032	920	5,600
		6 μm	237	265	113	61	1,000
		14 μm	6	6	4	2	36
		ISO code	18/15/10	18/15/10	17/14/9	17/13/8	20/17/12
		Evaluation	A	A	A	A	F

EP 4 130 212 A1

Table 2

			Example 4	Comparative Example 3	Comparative Example 4
5	Lubricating oil composition	High-viscosity base oil (AH)-1	-	-	-
10		High-viscosity base oil (AH)-2	41.71	45.05	45.05
15		Low-viscosity base oil (AL)-2	-	-	-
20		Low-viscosity base oil (AL)-2	-	-	-
25		Low-viscosity base oil (AL)-3	37.5	36.16	36.16
30		Another base oil (AZ)	10	10	10
35		Diluted product of silicone- based anti-foaming agent (B) (unit: % by mass)	0.0998	0.099	0.09999
40		Silicone-based anti- foaming agent (B)	0.0002	0.001	0.00001
45		Phenol-based antioxidant	0.5	0.5	0.5
50		Amine-based antioxidant	0.5	0.5	0.5
55		Dihydroxycarbyl sulfide	0.3	0.3	0.3
		Alkylthiophosphoric acid ester	0.4	0.4	0.4
		Alkyl thiocarbamate	1.3	1.3	1.3
		Alkylbenzotriazole	0.05	0.05	0.05
		Acidic phosphoric acid ester	0.22	0.22	0.22
		Alkylamine	0.36	0.36	0.36
		EO-PO copolymer	0.01	0.01	0.01
		Alkenyl succinimide	0.05	0.05	0.05
		OCP	7	5	5
		Total (unit: % by mass)	100	100	100
		VG	320	320	320
		Silicon atom content in lubricating oil composition (theoretical value, unit: ppb by mass)	810	4049	40

(continued)

			Example 4	Comparative Example 3	Comparative Example 4
Evaluation	Evaluation of foaming property	Foaming amount after 1,440 minutes (mL)	30	200	270
		Foaming amount after 2,880 minutes (mL)	30	200	270
		Evaluation	A	F	F
	Evaluation of detergency	4 μm	737	11080	605
		6 μm	83	2046	110
		14 μm	4	84	12
		ISO code	17/14/9	21/18/14	16/14/11
		Evaluation	A	F	A

[0170] From Table 1, the following can be seen.

[0171] It can be seen that in Examples 1 to 3 in which the silicon atom content in the lubricating oil composition is in a range of 50 ppb by mass to 4,000 ppb by mass, both long-term anti-foaming performance and detergency can be obtained.

[0172] On the other hand, it can be seen that in Comparative Example 1 in which the silicon atom content in the lubricating oil composition is less than 50 ppb by mass, the long-term anti-foaming performance cannot be ensured.

[0173] In addition, it can be seen that in Comparative Example 2 in which the silicon atom content in the lubricating oil composition is more than 4,000 ppb by mass, the detergency cannot be ensured.

[0174] In addition, the same as above can be seen from the evaluation results shown in Table 2 in which a lubricating oil additive other than the silicone-based anti-foaming agent (B) is also blended in the lubricating oil composition.

[0175] That is, it can be seen that in Example 4 in which the silicon atom content in the lubricating oil composition is in a range of 50 ppb by mass to 4,000 ppb by mass, both long-term anti-foaming performance and detergency can be obtained.

[0176] On the other hand, it can be seen that in Comparative Example 3 in which the silicon atom content in the lubricating oil composition is less than 50 ppb by mass, the long-term anti-foaming performance cannot be ensured.

[0177] In addition, it can be seen that in Comparative Example 4 in which the silicon atom content in the lubricating oil composition is more than 4,000 ppb by mass, the detergency cannot be ensured.

Claims

1. A lubricating oil composition comprising:

a base oil (A); and
a silicone-based anti-foaming agent (B), wherein
a silicon atom content is 50 ppb by mass to 4,000 ppb by mass based on a total amount of the lubricating oil composition.

2. The lubricating oil composition according to claim 1, wherein
the base oil (A) is one or more selected from the group consisting of a synthetic oil (A1) and a mineral oil (A2).

3. The lubricating oil composition according to claim 1, wherein
the base oil (A) is two or more selected from the group consisting of a synthetic oil (A1) and a mineral oil (A2).

4. The lubricating oil composition according to claim 1, wherein
the base oil (A) is two or more selected from the group consisting of a synthetic oil (A1) and a mineral oil (A2) and
having different kinematic viscosities at 40°C.

EP 4 130 212 A1

5. The lubricating oil composition according to any one of claims 1 to 4, wherein a total content of the base oil (A) and the silicone-based anti-foaming agent (B) is 75% by mass or more and 94.9% by mass or less based on the total amount of the lubricating oil composition.
- 5 6. The lubricating oil composition according to any one of claims 1 to 5, wherein the silicone-based anti-foaming agent (B) comprises one or more selected from the group consisting of polydimethylsiloxane and fluorinated polysiloxane.
- 10 7. The lubricating oil composition according to any one of claims 1 to 6, further comprising:
one or more lubricating oil additives selected from the group consisting of an antioxidant, an extreme pressure agent, an anti-emulsifier, a rust inhibitor, a viscosity index improver, a pour point depressant, a metal deactivator, an ash-free detergent dispersant, and a friction modifier.
- 15 8. The lubricating oil composition according to any one of claims 1 to 7, which is used as an accelerator oil for a wind turbine, a hydraulic oil, a compressor oil, a gear oil, a cutting oil, a machine tool oil, a refrigerator oil, a turbine oil, an internal combustion engine oil, a transmission oil, or an axle unit oil for a vehicle.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/011432

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A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. C10M169/04(2006.01)i, C10N30/04(2006.01)n, C10N30/18(2006.01)n, C10N40/04(2006.01)n, C10N40/08(2006.01)n, C10N40/12(2006.01)n, C10N40/22(2006.01)n, C10N40/25(2006.01)n, C10N40/30(2006.01)n, C10M101/02(2006.01)i, C10M139/04(2006.01)i, C10M155/02(2006.01)

FI: C10M155/02, C10M169/04, C10M139/04, C10M101/02, C10N40/08, C10N40/04, C10N40/30, C10N40/22, C10N40/12, C10N40/25, C10N30/18, C10N30/04

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)

Int. Cl. C10M169/04, C10N30/04, C10N30/18, C10N40/04, C10N40/08, C10N40/12, C10N40/22, C10N40/25, C10N40/30, C10M101/02, C10M139/04, C10M155/02

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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)

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 2008-120996 A (SHOWA SHELL SEKIYU KABUSHIKI KAISHA) 29 May 2008, paragraphs [0002]-[0004], [0009], [0020], [0022], examples 1-4	1-8
X	JP 2009-138037 A (HITACHI APPLIANCES, INC.) 25 June 2009, paragraphs [0007], [0008], [0023], [0044]-[0047], table 2	1-8
X	JP 2001-508357 A (EXXON RESEARCH ENGINEERING CO.) 26 June 2001, table 7, p. 7, lines 5-15, p. 8, line 21 to p. 9, line 5	1-8
X	JP 11-209778 A (NISSEKI MITSUBISHI CORP.) 03 August 1999, table 1, paragraphs [0008]-[0011]	1-5, 7-8
A		6

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

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* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

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Date of the actual completion of the international search
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INTERNATIONAL SEARCH REPORT		International application No. PCT/JP2021/011432
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 45-19249 B1 (MOBIL OIL CORPORATION) 01 July 1970, column 3, line 45 to column 4, line 45, column 7, lines 27-38, table 4, claims	1-8

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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/011432

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JP 2008-120996 A	29.05.2008	WO 2008/046862 A1 p. 1, line 6 to p. 2, line 14, p. 4, lines 11-17, p. 8, lines 14-22, p. 8, line 32 to p. 9, line 9, examples 1-4 (Family: none)	
JP 2009-138037 A	25.06.2009		
JP 2001-508357 A	26.06.2001	US 6090758 A table 7, column 3, lines 40-55, column 4, lines 32-49 WO 1998/030306 A1 EP 954365 A CA 2274707 A (Family: none)	
JP 11-209778 A	03.08.1999		
JP 45-19249 B1	01.07.1970	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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