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(54) LUBRICANT COMPOSITION

(57) The present invention relates to a lubricating oil composition which has a low viscosity, and exhibits a low evaporativity, an excellent oil film retainability, and an excellent cleanliness at high temperature. To this end, the present invention provides a lubricating oil composition including a base oil (A) containing an olefin-based polymer (A1), a viscosity index improver (B), and an imide-based dispersant (C), in which a first olefin-based polymer (A1-1) having a kinematic viscosity at 100°C of 3.0 mm^2/s or more is contained as the olefin-based polymer (A1), and a content of the first olefin-based polymer (A1-1) is 30% by mass or more based on a total amount of the base oil (A), a second olefin-based polymer (A1-2) having a kinematic viscosity at 100°C of less than 3.0 mm^2/s is not contained as the olefin-based polymer (A1), or is contained in a content of less than 18.5% by mass based on the total amount of the base oil (A), a content of a resin component (B1) derived from the viscosity index improver (B) is 0.01% by mass or more based on a total amount of the lubricant composition, a content of nitrogen atoms derived from the imide-based dispersant (C) is 0.06% by mass or more based on the total amount of the lubricant composition, a content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is more than 0.001 in terms of a mass ratio, the kinematic viscosity at 100°C is 5.0 mm^2/s or more and less than 7.1 mm^2/s, and an aniline point is 95°C or higher.

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Description

Technical Field

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

Background Art

[0002] Recently, from the viewpoint of reducing an environmental load, vehicles such as automobiles are required to improve a fuel consumption reducing performance. As a method of improving the fuel consumption reducing performance, a method is known which lowers the viscosity of a lubricating oil composition to reduce the viscous resistance of the lubricating oil composition, thereby reducing an energy loss (see, e.g., PTL 1).

Citation List

Patent Literature

[0003] PTL 1: JP 2004-137317 A

Summary of Invention

Technical Problem

[0004] However, when the viscosity of the lubricating oil composition is lowered, an evaporation loss of the lubricating oil composition easily increases, and it becomes difficult to maintain a sufficient amount of oil necessary for lubricating engine parts. Further, an oil film may not be appropriately retained on a sliding portion or the like inside an engine. Thus, engine parts and others are easily damaged due to their fatigue or wear. These problems easily occur especially in a lubricating oil composition used in an environment with a high thermal load, such as an engine equipped with a forced-induction device.

[0005] Thus, there is a demand for a lubricating oil composition having a low viscosity, a low evaporativity, and an excellent performance of appropriately retaining an oil film on a sliding portion or the like inside an engine (hereinafter, also referred to as an "oil film retainability"). Further, from the viewpoint of producing a lubricating oil composition with an excellent long drain property or the like, the lubricating oil composition is also required to have a cleanliness at high temperature.

[0006] Further, the lubricating oil composition is also required to have a performance of improving a compatibility with a rubber material used for a sealing material or the like so as to suppress a swelling or hardening of the rubber material.

[0007] However, no sufficient study has been conducted on a lubricating oil composition that satisfies all of the requirements described above.

[0008] An object of the present invention is to provide a lubricating oil composition having the low viscosity, the low evaporativity, the excellent oil film retainability, the cleanliness at high temperature, and furthermore, the excellent compatibility with the rubber material.

Solution to Problem

[0009] In order to solve the foregoing problems, the present inventors have diligently conducted studies on a low-viscosity lubricating oil composition of which kinematic viscosity at 100°C falls in the range of 5.0 mm^2/s or more and less than 7.1 mm^2/s, and completed the present invention.

[0010] The present invention relates to [1] and [2] below.

> [1] A lubricating oil composition comprising a base oil (A) containing an olefin-based polymer (A1), a viscosity index improver (B), and an imide-based dispersant (C),
>
> > wherein a first olefin-based polymer (A1-1) having a kinematic viscosity at 100°C of 3.0 mm^2/s or more is contained as the olefin-based polymer (A1), and a content of the first olefin-based polymer (A1-1) is 30% by mass or more based on a total amount of the base oil (A),
> > a second olefin-based polymer (A1-2) having a kinematic viscosity at 100°C of less than 3.0 mm^2/s is not contained as the olefin-based polymer (A1), or is contained in a content of less than 18.5% by mass based on the total amount of the base oil (A),

a content of a resin component (B1) derived from the viscosity index improver (B) is 0.01% by mass or more based on a total amount of the lubricating oil composition,
a content of nitrogen atoms derived from the imide-based dispersant (C) is 0.06% by mass or more based on the total amount of the lubricating oil composition,
a content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is more than 0.001 in terms of a mass ratio,
the kinematic viscosity at 100°C is 5.0 mm^2/s or more and less than 7.1 mm^2/s, and
an aniline point is 95°C or higher.

[2] A method for lubricating an internal combustion engine using the lubricating oil composition according to [1] above.

Advantageous Effects of Invention

[0011] According to the present invention, it is possible to provide a lubricating oil composition having a low viscosity and exhibiting a low evaporativity, an excellent oil film retainability, a cleanliness at high temperature, and an excellent compatibility with a rubber material.

Description of Embodiments

[0012] In this specification, lower and upper limit values described in a stepwise manner for preferable numerical ranges (e.g., ranges for contents or the like) may be independently combined. For example, from the description "preferably 10 to 90, and more preferably 30 to 60", the "preferable lower limit value 10" and the "more preferable upper limit value 60" may be combined to obtain a range of "10 to 60".

[0013] In this specification, numerical values in Examples may be used as upper or lower limit values.

[0014] In this specification, a numerical range expressed as "AA to BB" indicates "AA or more and BB or less", unless otherwise specified.

[0015] In this specification, a mass average molecular weight (Mw) and a number average molecular weight (Mn) of each component are values measured by the gel permeation chromatography (GPC) according to the standard polystyrene conversion, and specifically, indicate values measured by the method described in the section of Examples.

[0016] In this specification, for example, the expression "(meth)acrylate" is used to indicate both "acrylate" and "methacrylate", and the same applies to other similar terms or the same expressions.

[0017] In this specification, a "kinematic viscosity at 40°C" is also referred to as a "40°C kinematic viscosity". Further, a "kinematic viscosity at 100°C" is also referred to as a "100°C kinematic viscosity".

[Embodiment of Lubricating Oil Composition]

[0018] The lubricating oil composition of the present invention comprises a base oil (A) containing an olefin-based polymer (A1), a viscosity index improver (B), and an imide-based dispersant (C),

wherein a first olefin-based polymer (A1-1) having a kinematic viscosity at 100°C of 3.0 mm^2/s or more is contained as the olefin-based polymer (A1), and a content of the first olefin-based polymer (A1-1) is 30% by mass or more based on a total amount of the base oil (A),
a second olefin-based polymer (A1-2) having a kinematic viscosity at 100°C of less than 3.0 mm^2/s is not contained as the olefin-based polymer (A1), or is contained in a content of less than 18.5% by mass based on the total amount of the base oil (A),
a content of a resin component (B1) derived from the viscosity index improver (B) is 0.01% by mass or more based on a total amount of the lubricating oil composition,
a content of nitrogen atoms derived from the imide-based dispersant (C) is 0.06% by mass or more based on the total amount of the lubricating oil composition,
a content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is more than 0.001 in terms of a mass ratio,
the kinematic viscosity at 100°C is 5.0 mm^2/s or more and less than 7.1 mm^2/s, and
an aniline point is 95°C or higher.

[0019] In order to solve the problems described above, the present inventors have diligently conducted studies on a low-viscosity lubricating oil composition of which kinematic viscosity at 100°C falls in the range of 5.0 mm^2/s or more and less than 7.1 mm^2/s.

[0020] As a result, the present inventors have found that the problems can be solved by a lubricating oil composition which uses a base oil containing a specific olefin-based polymer in a specific amount and containing another olefin-based polymer different from the specific olefin-based polymer in a small content, such that a ratio of a resin component derived from a viscosity index improver and the specific olefin-based polymer is adjusted to a specific ratio, to adjust the content of the resin component derived from the viscosity index improver, the content of an imide-based dispersant and others to specific ranges, and further, an aniline point is adjusted to a specific range. Based on this finding, the present inventors have further conducted various studies and completed the present invention.

[0021] In the descriptions herein below, the "base oil (A)", the "viscosity index improver (B)", and the "imide-based dispersant (C)" are also referred to as a "component (A)", a "component (B)", and a "component (C)", respectively.

[0022] The lubricating oil composition according to an embodiment of the present invention may be composed of only the components (A), (B), and (C), and may contain components other than the components (A), (B), and (C) as long as the effects of the present invention are not impaired.

[0023] In the lubricating oil composition according to an embodiment of the present invention, the total content of the components (A), (B), and (C) is preferably 70% by mass to 100% by mass, more preferably 75% by mass to 100% by mass, and still more preferably 80% by mass to 100% by mass, based on the total amount of the lubricating oil composition.

[0024] Hereinafter, each component contained in the lubricating oil composition of the present invention will be described in detail.

«Base Oil (A)»

[0025] The lubricating oil composition of the present invention contains the base oil (A) containing the olefin-based polymer (A1).

[0026] In the lubricating oil composition of the present invention, a first olefin-based polymer (A1-1) having a kinematic viscosity at 100°C of 3.0 mm^2/s or more is contained as the olefin-based polymer (A1). The content of the first olefin-based polymer (A1-1) is 30% by mass or more based on the total amount of the base oil (A).

[0027] When the content of the first olefin-based polymer (A1-1) is less than 30% by mass based on the total amount of the base oil (A), the lubricating oil composition may not exhibit the low evaporativity.

[0028] Here, from the viewpoint of facilitating the production of the lubricating oil composition exhibiting the low evaporativity, the 100°C kinematic viscosity of the first olefin-based polymer (A1-1) is preferably 3.1 mm^2/s or more, more preferably 3.2 mm^2/s or more, and still more preferably 3.3 mm^2/s or more. Further, from the viewpoint of ensuring the fuel consumption reducing performance of the lubricating oil composition, the 100°C kinematic viscosity of the olefin-based polymer (A1) is preferably 7.0 mm^2/s or less, more preferably 5.0 mm^2/s or less, still more preferably 4.0 mm^2/s or less, and yet still more preferably 3.7 mm^2/s or less.

[0029] The upper and lower limit values of the numerical ranges above may be arbitrarily combined. Specifically, the viscosity is preferably 3.1 mm^2/s to 7.0 mm^2/s, more preferably 3.2 mm^2/s to 5.0 mm^2/s, still more preferably 3.3 mm^2/s to 4.0 mm^2/s, and yet still more preferably 3.3 mm^2/s to 3.7 mm^2/s.

[0030] In this specification, the 100°C kinematic viscosity of the base oil is a value measured in conformity with JIS K2283:2000.

[0031] Further, from the viewpoint of facilitating the production of the lubricating oil composition exhibiting the low evaporativity, the content of the first olefin-based polymer (A1-1) is preferably 40% by mass to 100% by mass, more preferably 50% by mass to 100% by mass, and still more preferably 60% by mass to 100% by mass, based on the total amount of the base oil (A).

[0032] Hereinafter, the first olefin-based polymer (A1-1) will be described in detail.

<First Olefin-Based Polymer (A1-1)>

[0033] The first olefin-based polymer (A1-1) is a polymer containing a structural unit (a1) derived from α-olefin (hereinafter, also referred to as a "monomer (a1)").

[0034] The first olefin-based polymer (A1-1) may be used either alone or in combination of two or more thereof.

[0035] The carbon number of the monomer (a1) is preferably 6 or more, and more preferably 8 or more, from the viewpoint of facilitating the achievement of the effects of the present invention. Further, the carbon number is preferably 20 or less, more preferably 16 or less, and still more preferably 12 or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the carbon number is preferably 6 to 20, more preferably 8 to 16, and still more preferably 8 to 12. Further, the carbon number is yet still more preferably 10. In addition, the monomer (a1) may be linear or branched.

[0036] Specific examples of the monomer (a1) include, preferably, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene, 1-undecene, 1-dodecene, 1-tridecene, 1-tetradecene, 1-pentadecene, 1-hexadecene, 1-heptadecene, 1-octadecene, 1-nonadecene, and 1-eicosene. Among these monomers, 1-octene, 1-nonene, 1-decene, 1-undecene, 1-dodecene, 1-tridecene, 1-tetradecene, 1-pentadecene, 1-hexadecene, and 1-heptadecene are more preferable, 1-octene, 1-nonene, 1-decene, 1-undecene, and 1-dodecene are still more preferable, and 1-decene is still more preferable.

[0037] The monomer (a1) may be used either alone or in combination of two or more thereof.

[0038] Here, from the viewpoint of facilitating the achievement of the effects of the present invention, it is preferable that the first olefin-based polymer (A1-1) contains 1-decene as the monomer (a1).

[0039] The content of 1-decene is preferably 80 to 100% by mass, more preferably 90 to 100% by mass, still more preferably 95 to 100% by mass, and yet still more preferably 100% by mass, based on the total amount of the monomer contained in the first olefin-based polymer (A1-1).

[0040] When the first olefin-based polymer (A1-1) contains α-olefin other than 1-decene as the monomer (a1), the α-olefin other than 1-decene may be one or more selected from the α-olefins other than 1-decene among the α-olefins described above as examples of the monomer (a1).

[0041] Further, from the viewpoint of facilitating the achievement of the effects of the present invention, the first olefin-based polymer (A1-1) contains preferably a dimer to a pentamer of the monomer (a1), more preferably a dimer to a tetramer of the monomer (a1), and still more preferably a trimer of the monomer (a1).

[0042] For example, when the monomer (a1) is 1-decene, the first olefin-based polymer (A1-1) contains preferably a decene trimer.

[0043] Further, from the viewpoint of facilitating the achievement of the effects of the present invention, and ensuring the performance of the present invention as an engine oil, it is preferable that the first olefin polymer (A1-1) has a terminal vinylidene double bond reduced by a hydrogenation treatment. That is, the first olefin-based polymer (A1-1) is preferably partial hydride, and more preferably complete hydride.

<Method of Polymerizing First Olefin-Based Polymer (A1-1)>

[0044] A method of polymerizing the first olefin-based polymer (A1-1) is not particularly limited, and a known method may be appropriately adopted which can polymerize the first olefin-based polymer (A1-1) through a polymerization reaction of α-olefin (e.g., a polymerization method using an acid catalyst such as a BF_3 catalyst).

[0045] Here, from the viewpoint of increasing the content ratio (purity) of a desired polymer (e.g., a decene trimer) in the first olefin-based polymer (A1-1) to facilitate the achievement of the effects of the present invention, it is preferable to adopt a polymerization method using a metallocene catalyst.

· Metallocene Catalyst

[0046] The metallocene catalyst is preferably a complex containing an element belonging to Group 4 and having a conjugated carbon 5-membered ring.

[0047] While the element belonging to Group 4 may be one or more selected from titanium, zirconium, and hafnium, zirconium is preferable.

[0048] Further, as the complex having the conjugated carbon 5-membered ring, a complex having a substituted or unsubstituted cyclopentadienyl ligand is preferable.

[0049] Specific examples of the metallocene catalyst include bis(n-octadecylcyclopentadienyl)zirconium dichloride, bis(trimethylsilylcyclopentadienyl)zirconium dichloride, bis(tetrahydroindenyl)zirconium dichloride, bis[(t-butyldimethylsilyl)cyclop entadienyl] zirconium dichloride, bis(di-t-butylcyclopentadienyl)zirconium dichloride, (ethylidene-bisindenyl)zirconium dichloride, biscyclopentadienyl zirconium dichloride, ethylidenebis(tetrahydroindenyl)zirconium dichloride, and bis[3,3-(2-methyl-benzindenyl)]dimethylsilanediyl zirconium dichloride.

[0050] The metallocene catalyst may be used either alone or in combination of two or more thereof.

· Co-Catalyst

[0051] When the polymerization method using the metallocene catalyst is adopted, an oxygen-containing organoaluminum compound may be used as a co-catalyst together with the metallocene catalyst.

[0052] Specific examples of the oxygen-containing organoaluminum compound include methylarmoxane, ethylarmoxane, and isobutylarmoxane.

[0053] The oxygen-containing organoaluminum compound may be used either alone or in combination of two or more thereof.

· Mixing Ratio of Co-Catalyst to Metallocene Catalyst

[0054] From the viewpoint of obtaining the first olefin-based polymer (A1-1) which more easily achieves the effects of the present invention, the mixing ratio of the co-catalyst to the metallocene catalyst (co-catalyst/metallocene catalyst) is preferably 5 to 1,000, more preferably 7 to 500, and still more preferably 10 to 200, in terms of a molar ratio.

<Method of Producing First Olefin-Based Polymer (A1-1)>

[0055] It is preferable that the first olefin-based polymer (A1-1) is produced through the following steps (i) to (iii).

- Step (i): Polymerizing the monomer (a1) using the metallocene catalyst
- Step (ii): Treating the polymer obtained in step (i) with alkali.
- Step (iii): Hydrogenating the polymer treated with alkali in step (ii)

· Step (i)

[0056] Step (i) may be performed in a batch manner or a continuous manner.

[0057] Further, the above-described oxygen-containing organoaluminum compound which is the co-catalyst may be used together with the metallocene catalyst.

[0058] In step (i), the polymerization of the monomer (a1) may be progressed in the presence of one or more organic solvents selected from benzene, ethylbenzene, and toluene.

[0059] It is preferable that the polymerization reaction in step (i) is performed under the condition that a reaction temperature is 15 to 100°C, and a reaction pressure is an atmospheric pressure to 0.2 MPa.

[0060] After the polymerization is sufficiently progressed, the reaction may be terminated by adding water or alcohol.

· Step (ii)

[0061] Step (ii) treats the polymer obtained in step (i) with alkali, to remove the catalyst components such as the metallocene catalyst and the oxygen-containing organoaluminum compound.

[0062] Examples of the alkali used in step (ii) include one or more selected from sodium hydroxide, sodium carbonate, and sodium hydrogencarbonate.

[0063] After a solution obtained by dissolving the alkali in water or alcohol such as methanol, ethanol, or propanol is added to the reaction solution containing the polymer, the contents are sufficiently stirred, and subjected to a liquid separating operation to extract an organic layer, so that the catalyst components can be removed.

[0064] The pH of the obtained solution is preferably 9 or higher. Further, the temperature of the obtained solution is preferably 20 to 100°C.

· Step (iii)

[0065] Step (iii) hydrogenates the polymer treated with alkali in step (iii) to convert the polymer into hydride. The hydride may be partial hydride, and is preferably complete hydride.

[0066] The hydrogenation treatment in step (iii) is performed by filling a hydrogen gas in a system containing the polymer, and performing a heating in the presence of a metal catalyst.

[0067] As the metal catalyst used in the hydrogenation treatment, for example, one or more selected from a nickel-based catalyst, a cobalt-based catalyst, a palladium-based catalyst, and a platinum-based catalyst may be used, and specifically, one or more selected from a diatomaceous earth-supported nickel catalyst, a cobalt trisacetyl acetonate/organoaluminum catalyst, an active carbon-supported palladium catalyst, and an alumina-supported platinum catalyst may be used.

[0068] The temperature condition of the hydrogenation treatment is usually 200°C or lower, and is appropriately set according to a type of the metal catalyst used. For example, when a nickel-based catalyst is used, the temperature condition is preferably 150 to 200°C. When a palladium-based catalyst or a platinum-based catalyst is used, the temperature condition is preferably 50 to 150°C. When a homogeneous reducing agent such as a cobalt trisacetyl acetonate/organoaluminum catalyst is used, the temperature condition is preferably 20 to 100°C.

[0069] Further, the hydrogen pressure during the hydrogenation treatment is preferably an atmospheric pressure to 20 MPa.

[0070] It is preferable to perform a distillation treatment after the hydrogenation treatment, to remove a by-product.

[0071] It is preferable that the distillation treatment is performed under the condition that the temperature is 180 to 450°C, and the pressure is 0.01 to 100 kPa.

<Second Olefin-Based Polymer (A1-2)>

[0072] In the lubricating oil composition of the present invention, a second olefin-based polymer (A1-2) having a 100°C kinematic viscosity of less than 3.0 mm^2/s is not contained as the olefin-based polymer (A1), or is contained in the content of less than 18.5% by mass based on the total amount of the base oil (A).

[0073] When the content of the second olefin-based polymer (A1-2) is 18.5% by mass or more based on the total amount of the base oil (A), the lubricating oil composition does not exhibit the low evaporativity.

[0074] As the kinematic viscosity at 100°C of the second olefin-based polymer (A1-2) is low (i.e., less than 2.5 mm^2/s, less than 2.3 mm^2/s, or especially less than 2.1 mm^2/s), it becomes difficult to ensure the low evaporativity of the lubricating oil composition.

[0075] Accordingly, the content of the second olefin-based polymer (A1-2) is preferably as small as possible, from the viewpoint of facilitating the production of the lubricating oil composition having the low evaporativity. Specifically, the content of the second olefin-based polymer (A1-2) is preferably 0% by mass to 15% by mass, more preferably 0% by mass to 10% by mass, still more preferably 0% by mass to 5% by mass, and yet still more preferably 0% by mass to 1% by mass, based on the total amount of the base oil (A), and it is even yet still more preferable that the second olefin-based polymer (A1-2) is absent.

[0076] The second olefin-based polymer (A1-2) may be used either alone or in combination of two or more thereof.

[0077] Further, the second olefin-based polymer (A1-2) may be produced by, for example, using the same method as the above-described method of producing the first olefin-based polymer (A1-1) and changing a distillation temperature, etc.

<Additional Base Oil>

[0078] In the lubricating oil composition according to an embodiment of the present invention, the base oil (A) may contain an additional base oil different from the base oil described above. For example, in the lubricating oil composition according to an embodiment of the present invention, the base oil (A) may contain one or more selected from the group consisting of a mineral oil (A2), and a synthetic oil (A3) other than the first olefin-based polymer (A1-1) and the second olefin-based polymer (A1-2).

[0079] The content of the additional base oil is 70% by mass or less based on the total amount of the base oil (A), and is preferably 0% by mass to 60% by mass, more preferably 0% by mass to 50% by mass, still more preferably 0% by mass to 40% by mass, from the viewpoint of further facilitating the achievement of the effects of the present invention.

[0080] Hereinafter, the mineral oil (A2) and the synthetic oil (A3) will be described in detail.

(Mineral Oil (A2))

[0081] As the mineral oil (A2), a general mineral oil used as a base oil of a lubricating oil may be used without being particularly limited, as long as the effects of the present invention are not impaired.

[0082] Specific examples of the mineral oil (A2) include: an atmospheric pressure residual oil obtained by subjecting a crude oil, such as a paraffinic crude oil, an intermediate base crude oil, and a naphthenic crude oil to an atmospheric pressure distillation; a distillate oil obtained by subjecting the atmospheric pressure residual oil to a reduced-pressure distillation; a mineral oil obtained by subjecting the distillate oil to one or more treatments of a solvent deasphalting, a solvent extraction, a hydrocracking, a solvent dewaxing, a catalytic dewaxing, a hydrorefining, etc.; and a wax isomerized mineral oil.

[0083] The mineral oil (A2) may be used either alone or in combination of two or more thereof.

[0084] Here, from the viewpoint of facilitating the production of the lubricating oil composition exhibiting the low evaporativity, the content of the mineral oil (A2) is preferably 50% by mass or less, more preferably 40% by mass or less, and still more preferably 35% by mass or less, based on the total amount of the base oil (A).

[0085] Meanwhile, in the lubricating oil composition according to an embodiment of the present invention, it is preferable to add the mineral oil (A2) in a specific amount or more within a range in which the content of the mineral oil (A2) does not exceed the upper limit values described above. As a result, while reducing the cost for the base oil (A), the aniline point of the lubricating oil composition can easily be adjusted to 95°C or higher, so that the compatibility with the rubber material can easily be improved, and the effect of suppressing the swelling or hardening of the rubber material can easily be achieved. From this viewpoint, the content of the mineral oil (A2) is preferably 10% by mass or more, more preferably 20% by mass or more, and still more preferably 25% by mass or more, based on the total amount of the base oil (A).

[0086] In this case, the total content of the first olefin-based polymer (A1-1) and the mineral oil (A2) is preferably 70% by mass to 100% by mass, more preferably 80% by mass to 100% by mass, still more preferably 90% by mass to 100% by mass, yet still more preferably 95% by mass to 100% by mass, and even yet still more preferably 100% by mass, based on the total amount of the base oil (A).

[0087] Further, in this case, the content ratio of the first olefin-based polymer (A1-1) and the mineral oil (A2) [(A1-1)/(A2)] is preferably 50/50 or more, more preferably 60/40 or more, and still more preferably 65/35 or more, in terms of a mass ratio. Further, the content ratio is preferably 90/10 or less, more preferably 80/20 or less, and still more preferably 75/25 or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the content ratio is preferably 50/50 to 90/10, more preferably 60/40 to 80/20, and still more preferably 65/35 to 75/25.

[0088] The mineral oil (A2) is preferably a mineral oil classified into Group II or III of the base oil category of the American Petroleum Institute (API).

[0089] From the viewpoint of facilitating the achievement of the effects of the present invention, the 100°C kinematic viscosity of the mineral oil (A2) is preferably 1.0 mm^2/s or more, more preferably 1.5 mm^2/s or more, and still more preferably 2.0 mm^2/s or more. Further, the 100°C kinematic viscosity is preferably 7.5 mm^2/s or less, more preferably 5.0 mm^2/s or less, and still more preferably 3.5 mm^2/s or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the 100°C kinematic viscosity is preferably 1.0 mm^2/s to 7.5 mm^2/s, more preferably 1.5 mm^2/s to 5.0 mm^2/s, and still more preferably 2.0 mm^2/s to 3.5 mm^2/s.

[0090] The viscosity index of the mineral oil (A2) is preferably 90 or more, more preferably 95 or more, and still more preferably 100 or more.

[0091] When the mineral oil (A2) is a mixture of two or more mineral oils, the kinematic viscosity and the viscosity index of the mixture may fall within the ranges described above.

(Synthetic Oil (A3))

[0092] As the synthetic oil (A3), a general synthetic oil used as a base oil of a lubricating oil may be used without being particularly limited, as long as the effects of the present invention are not impaired.

[0093] Specific examples of the synthetic oil (A3) include polyphenyl ether, alkylbenzene, alkylnaphthalene, polyphenyl-based hydrocarbon, an ester-based oil, a naphthene-based synthetic oil, a glycol-based synthetic oil, and a GTL (gas to liquids) base oil obtained by isomerizing a wax produced from a natural gas through the Fisher-Tropsch method or the like (GTL wax).

[0094] Here, from the viewpoint of facilitating the achievement of the effects of the present invention, the content of the synthetic oil (A3) is 70% by mass or less based on the total amount of the base oil (A), and from the viewpoint of further facilitating the achievement of the effects of the present invention, the content of the synthetic oil (A3) is preferably 0% by mass to 60% by mass, more preferably 0% by mass to 50% by mass, and still more preferably 0% by mass to 40% by mass.

[0095] Here, from the viewpoint of facilitating the adjustment of the aniline point to 95°C or higher so as to improve the compatibility with the rubber material and suppress the swelling or hardning of the rubber material, it is preferable that the base oil (A) does not contain an ester-based oil (A3-1). Alternatively, even when the base oil (A) contains the ester-based oil (A3-1), the content of the ester-based oil (A3-1) is preferably 15% by mass or less, and more preferably 10% by mass or less, based on the total amount of the base oil (A).

[0096] From the same viewpoint, it is preferable that the base oil (A) does not contain a naphthene-based synthetic oil (A3-2). Alternatively, even when the base oil (A) contains the naphthene-based synthetic oil (A3-2), the content of the naphthene-based synthetic oil (A3-2) is preferably 15% by mass or less, and more preferably 10% by mass or less, based on the total amount of the base oil (A).

<<Viscosity Index Improver (B)>>

[0097] The lubricating oil composition of the present invention contains the viscosity index improver (B). In the lubricating oil composition of the present invention, the content of the resin component (B1) derived from the viscosity index improver (B) is 0.01% by mass or more based on the total amount of the lubricating oil composition.

[0098] When the content of the resin component (B1) derived from the viscosity index improver (B) is less than 0.01% by mass based on the total amount of the lubricating oil composition, the oil film retainability may not be sufficiently ensured.

[0099] Here, from the viewpoint of ensuring the favorable oil film retainability, the content of the resin component (B1) derived from the viscosity index improver (B) is preferably 0.10% by mass or more, more preferably 0.30% by mass or more, and still more preferably 0.50% by mass or more, based on the total amount of the lubricating oil composition. Further, from the viewpoint of the shear stability of the viscosity index improver (B), the content of the resin component (B1) is preferably 5.0% by mass or less, more preferably 4.0% by mass or less, still more preferably 3.0% by mass or less, and yet still more preferably 1.5% by mass or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the content is preferably 0.10% by mass to 5.0% by mass, more preferably 0.30% by mass to 4.0% by mass, still more preferably 0.50% by mass to 3.0% by mass, and yet still more preferably 0.50% by mass to 1.5% by mass.

[0100] The "resin component (B1) derived from the viscosity index improver (B)" indicates a polymer having a mass average molecular weight (Mw) of 1,000 or more and having a fixed repeating unit.

[0101] In the lubricating oil composition according to an embodiment of the present invention, the mass average molecular weight (Mw) of the resin component (B1) derived from the viscosity index improver (B) is preferably 200,000 to 1,000,000, more preferably 200,000 to 800,000, and still more preferably 200,000 to 700,000, from the viewpoint of obtaining the lubricating oil composition capable of stably exhibiting the excellent fuel consumption reducing performance and the excellent oil film retainability even when the composition is used under a wide temperature environment from a low temperature region to a high temperature region.

[0102] Further, in the lubricating oil composition according to an embodiment of the present invention, the molecular weight distribution (Mw/Mn) of the resin component (B1) derived from the viscosity index improver (B) (where Mw indicates the mass average molecular weight of the resin component (B1), and Mn indicates the number average molecular weight of the resin component (B1)) is preferably 8.00 or less, more preferably 7.00 or less, still more preferably 6.50 or less, yet still more preferably 6.00 or less, even yet still more preferably 5.00 or less, and even still more further preferably 3.00 or less, from the viewpoint of improving the fuel consumption reducing performance of the lubricating oil composition. The fuel consumption reducing performance of the lubricating oil composition containing the resin component (B1) together with the base oil (A) tends to be improved, as the molecular weight distribution of the resin component (B1) is small.

[0103] Further, the molecular weight distribution of the resin component (B1) is not particularly limited with respect to its lower limit value, but is usually 1.01 or more, preferably 1.05 or more, and more preferably 1.10 or more.

[0104] In the lubricating oil composition according to an embodiment of the present invention, the resin component (B1) derived from the viscosity index improver (B) contains one or more selected from, for example, non-dispersive polymethacrylate, dispersed polymethacrylate, and a comb-shaped polymer. The resin component (B1) may contain other resin components as long as the effects of the present invention are not impaired.

[0105] Here, from the viewpoint of facilitating the achievement of the effects of the present invention and lowering the viscosity of the lubricating oil composition in a low temperature region, the resin component (B1) derived from the viscosity index improver (B) is preferably a comb-shaped polymer (B1-1).

[0106] Hereinafter, the comb-shaped polymer (B1-1) will be described in detail.

<Comb-Shaped Polymer (B1-1)>

[0107] In the present invention, the "comb-shaped polymer (B1-1)" indicates a polymer having a structure having a large number of trigeminal branch points from which a high-molecular weight side chain comes out in a main chain thereof.

[0108] From the viewpoint of improving the fuel consumption reducing performance, the mass average molecular weight (Mw) of the comb-shaped polymer (B1-1) is preferably 100,000 or more, more preferably 200,000 or more, still more preferably 250,000 or more, yet still more preferably 300,000 or more, and even yet still more preferably 350,000 or more. Further, the mass average molecular weight (Mw) is preferably 1,000,000 or less, more preferably 800,000 or less, still more preferably 750,000 or less, even yet still more preferably 700,000 or less, and even still more further preferably 650,000 or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the mass average molecular weight (Mw) is preferably 100,000 to 1,000,000, more preferably 200,000 to 800,000, still more preferably 250,000 to 750,000, yet still more preferably 300,000 to 700,000, and even yet still more preferably 350,000 to 650,000.

[0109] The molecular weight distribution (Mw/Mn) of the comb-shaped polymer (B1-1) (where Mw indicates the mass average molecular weight of the comb-shaped polymer (B1-1), and Mn indicates the number average molecular weight of the comb-shaped polymer (B1-1)) is preferably 8.00 or less, more preferably 7.00 or less, still more preferably 6.50 or less, yet still more preferably 6.00 or less, even yet still more preferably 5.00 or less, and even still more further preferably 3.00 or less, from the viewpoint of improving the fuel consumption reducing performance of the lubricating oil composition. The fuel consumption reducing performance of the lubricating oil composition containing the comb-shaped polymer (B1-1) together with the base oil (A) tends to be improved, as the molecular weight distribution of the comb-shaped polymer (B1-1) is small.

[0110] Further, the molecular weight distribution of the comb-shaped polymer (B1-1) is not particularly limited with respect to its lower limit value, but is usually 1.01 or more, preferably 1.05 or more, and still more preferably 1.10 or more.

[0111] In the lubricating oil composition according to an embodiment of the present invention, the content of the comb-shaped polymer (B1-1) is preferably 0.10% by mass or more, more preferably 0.30% by mass or more, and still more preferably 0.50% by mass or more, based on the total amount of the lubricating oil composition.

[0112] Further, in the lubricating oil composition according to an embodiment of the present invention, the content of the comb-shaped polymer (B1-1) is preferably 5.0% by mass or less, more preferably 4.0% by mass or less, and still more preferably 3.0% by mass or less, based on the total amount of the lubricating oil composition.

[0113] The SSI (shear stability index) of the comb-shaped polymer (B-1) is preferably 12.0 or less, more preferably 10.0 or less, still more preferably 5.0 or less, yet still more preferably 3.0 or less, and even yet still more preferably 1.0 or less.

[0114] Further, the SSI of the comb-shaped polymer (B1) is not particularly limited with respect to its lower limit value, but is usually 0.1 or more, and preferably 0.2 or more.

[0115] In this specification, the SSI (shear stability index) of the comb-shaped polymer (B-1) expresses a percentage of a viscosity lowering by a shearing originated from a resin component in the comb-shaped polymer (B-1), and is a value measured in conformity with ASTM D6278. More specifically, the SSI is a value calculated according to the following calculation formula (1).

$$SSI = \frac{Kv_0 - Kv_1}{Kv_0 - Kv_{oil}} \times 100 \qquad (1)$$

[0116] In the formula (1) above, K_{v0} represents a value of a 100°C kinematic viscosity of a sample oil obtained by diluting a viscosity index improver containing a resin component in a mineral oil; and K_{v1} represents a value of a 100°C kinematic viscosity after the sample oil obtained by diluting the viscosity index improver containing the resin component in the mineral oil is caused to pass through a 30-cycle high-shear diesel injector according to the procedures of ASTM D6278. Further, K_{voil} represents a value of a 100°C kinematic viscosity of the mineral oil used for diluting the viscosity index improver.

[0117] The SSI value of the comb-shaped polymer (B-1) varies according to the structure of the comb-shaped polymer (B-1). Specifically, there are the following tendencies, and the SSI value of the comb-shaped polymer (B-1) may easily be adjusted in consideration of the tendencies. The following tendencies are merely an example, and the SSI value may be adjusted in consideration of matters other than the tendencies.

- When the side chain of the comb-shaped polymer (B1-1) is constituted of a macromonomer (x1), and the content of a structural unit (X1) derived from the macromonomer (x1) is 0.5 mol% or more based on the total amount of structural units, the SSI value of the comb-shaped polymer tends to be low.
- The SSI value tends to become low as the molecular weight of the macromonomer (x1) constituting the side chain of the comb-shaped polymer (B1-1) increases.

<Structural Unit of Comb-Shaped Polymer (B1-1)>

[0118] Hereinafter, the structural unit of the comb-shaped polymer (B-1) used in an embodiment of the present invention will be described.

[0119] The comb-shaped polymer (B1-1) is preferably a polymer having at least the structural unit (X1) derived from the macromonomer (x1). The structural unit (X1) corresponds to the "high-molecular weight side chain" described above.

[0120] In the present invention, the "macromonomer" described above indicates a high-molecular weight monomer having a polymerizable functional group, and is preferably a high-molecular weight monomer having the polymerizable functional group in an end thereof.

[0121] The shear stability of the comb-shaped polymer (B1-1) is low, as the comb-shaped polymer (B1-1) has a relatively long main chain with respect to a side chain. This property may be believed to contribute to the improvement of the fuel consumption reducing performance even in a low temperature region of about 50°C.

[0122] From the viewpoint described above, in the comb-shaped polymer (B1) used in an embodiment of the present invention, the content of the structural unit (X1) is preferably 0.1 mol% or more and less than 10 mol%, more preferably 0.2 to 7 mol%, still more preferably 0.3 to 5 mol%, and yet still more preferably 0.5 to 3 mol%, based on the total amount of structural units of the comb-shaped polymer (B1-1).

[0123] In this specification, the content of each structural unit in the comb-shaped polymer (B1-1) indicates a value calculated by analyzing the ^{13}C-NMR quantitative spectrum.

[0124] From the viewpoint described above, the number average molecular weight (Mn) of the macromonomer (x1) is preferably 300 or more, more preferably 500 or more, still more preferably 1,000 or more, yet still more preferably 2,000 or more, and especially preferably 4,000 or more, and is preferably 100,000 or less, more preferably 50,000 or less, still more preferably 20,000 or less, and yet still more preferably 10,000 or less.

[0125] Examples of the polymerizable functional group of the macromonomer (x1) include an acryloyl group (CH_2=CH-COO-), a methacryloyl group (CH_2=CCH_3-COO-), an ethenyl group (CH_2=CH-), a vinyl ether group (CH_2=CH-O-), an allyl group (CH_2=CH-CH_2-), an allyl ether group (CH_2=CH-CH_2-O-), a group represented by CH_2=CH-CONH-, and a group represented by CH_2=CCH_3-CONH-.

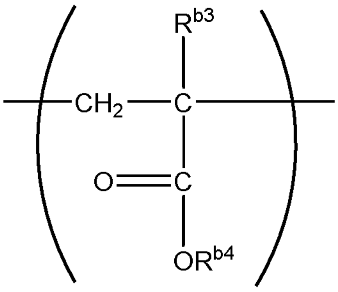
[0126] The macromonomer (x1) may also have one or more repeating units represented by the following general formulas (i) to (iii), in addition to the polymerizable functional group described above.

$$\left(R^{b1} \right)$$

(i)

$$\left(R^{b2}O \right)$$

(ii)



$$\left(CH_2 - \overset{\overset{\Large R^{b3}}{|}}{\underset{\underset{\underset{\Large OR^{b4}}{|}}{O=C}}{\overset{|}{C}}} \right)$$

(iii)

[0127] In the general formula (i) above, R^{b1} represents a linear or branched alkylene group having 1 to 10 carbon atoms, and specifically, examples thereof include a methylene group, an ethylene group, a 1,2-propylene group, a 1,3-propylene group, a 1,2-butylene group, a 1,3-butylene group, a 1,4-butylene group, a pentylene group, a hexylene group, a heptylene group, an octylene group, a nonylene group, a decylene group, and a 2-ethylhexylene group.

[0128] In the general formula (ii) above, R^{b2} represents a linear or branched alkylene group having 2 to 4 carbon atoms, and specifically, examples thereof include an ethylene group, a 1,2-propylene group, a 1,3-propylene group, a 1,2-butylene group, a 1,3-butylene group, and a 1,4-butylene group.

[0129] In the general formula (iii) above, R^{b3} represents a hydrogen atom or a methyl group.

[0130] Further, R^{b4} represents a linear or branched alkyl group having 1 to 10 carbon atoms, and specifically, examples thereof include a methyl group, an ethyl group, an n-propyl group, an n-butyl group, an n-pentyl group, an n-hexyl group, an n-heptyl group, an n-octyl group, an n-nonyl group, an n-decyl group, an isopropyl group, an isobutyl group, a sec-butyl group, a t-butyl group, an isopentyl group, a t-pentyl group, an isohexyl group, a t-hexyl group, an isoheptyl group, a t-heptyl group, a 2-ethylhexyl group, an isooctyl group, an isononyl group, and an isodecyl group.

[0131] When the macromonomer (x1) has a plurality of repeating units represented by each of the general formulas (i) to (iii) above, R^{b1}'s, R^{b2}'s, R^{b3}'s, and R^{b4}'s may be each the same as or different from each other.

[0132] In an embodiment of the present invention, the macromonomer (x1) is preferably a polymer having the repeating unit represented by the general formula (i) above, and more preferably a polymer having a repeating unit (X1-1) in which R^{b1} of the general formula (i) above is a 1,2-butylene group and/or a 1,4-butylene group.

[0133] The content of the repeating unit (X1-1) is preferably 1 to 100 mol%, more preferably 20 to 95 mol%, still more preferably 40 to 90 mol%, and yet still more preferably 50 to 80 mol%, based on the total amount (100 mol%) of structural units of the macromonomer (x1).

[0134] When the macromonomer (x1) is a copolymer having two or more repeating units selected from the general formulas (i) to (iii) above, the mode of the copolymer may be a block copolymer or a random copolymer.

[0135] The comb-shaped polymer (B1-1) used in an embodiment of the present invention may be a homopolymer composed of only the structural unit (X1) derived from one type of macromonomer (x1) or may be a copolymer containing the structural units (X1) derived from two or more types of macromonomers (x1).

[0136] Further, the comb-shaped polymer (B1-1) used in an embodiment of the present invention may be a copolymer containing a structural unit (X2) derived from a monomer (x2) other than the macromonomer (x1), together with the structural unit derived from the macromonomer (x1).

[0137] As for the specific structure of the comb-shaped polymer (B1-1) described above, a copolymer having a side chain containing the structural unit (X1) derived from the macromonomer (x1) relative to a main chain containing the structural unit (X2) derived from the monomer (x2) is preferable. More preferably, a copolymer may contain the structural unit (X1) derived from the macromonomer (x1) as a main chain, relative to the main chain containing the structural unit (X2) derived from the monomer (x2).

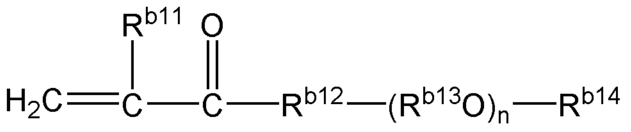
[0138] Examples of the monomer (x2) include a monomer (x2-a) represented by the following general formula (a1), alkyl (meth)acrylate (x2-b), a nitrogen atom-containing vinyl monomer (x2-c), a hydroxy group-containing vinyl monomer (x2-d), a phosphorus atom-containing monomer (x2-e), an aliphatic hydrocarbon-based vinyl monomer (x2-f), an alicyclic hydrocarbon-based vinyl monomer (x2-g), vinyl esters (x2-h), vinyl ethers (x2-i), vinyl ketones (x2-j), an epoxy group-containing vinyl monomer (x2-k), a halogen element-containing vinyl monomer (x2-1), ester of unsaturated polycarboxylic acid (x2-m), (di)alkyl fumarate (x2-n), (di)alkyl maleate (x2-o), and an aromatic hydrocarbon-based vinyl monomer (x2-p).

[0139] As the monomer (x2), monomers other than the nitrogen atom-containing vinyl monomer (x2-c), the phosphorus atom-containing monomer (x2-e), and the aromatic hydrocarbon-based vinyl monomer (x2-p) are preferable.

[0140] Further, as the monomer (x2), it is preferable to contain one or more selected from the monomer (x2-a) represented by the following general formula (a1), the alkyl (meth)acrylate (x2-b), and the hydroxy group-containing vinyl monomer (x2-d), and it is more preferable to contain at least the hydroxy group-containing vinyl monomer (x2-d).

(Monomer (x2-a) Represented by Following General Formula (a1))

[0141]



$$H_2C=\overset{R^{b11}}{\overset{|}{C}}-\overset{O}{\overset{\|}{C}}-R^{b12}-(R^{b13}O)_n-R^{b14} \qquad (a1)$$

[0142] In the general formula (a1) above, R^{b11} represents a hydrogen atom or a methyl group.

[0143] R^{b12} represents a single bond, a linear or branched alkylene group having 1 to 10 carbon atoms, -O-, or -NH-.

[0144] R^{b13} represents a linear or branched alkylene group having 2 to 4 carbon atoms. Further, the "n" represents an integer of 1 or more (preferably an integer of 1 to 20, and more preferably an integer of 1 to 5). When the "n" is an integer of 2 or more, a plurality of plural R^{b13}'s may be the same as or different from each other, and further, the $(R^{b13}O)_n$ moiety may be either a random bond or a block bond.

[0145] R^{b14} represents a linear or branched alkyl group having 1 to 60 carbon atoms (preferably 10 to 50 carbon atoms, and more preferably 20 to 40 carbon atoms).

[0146] Specific groups of the above-described "linear or branched alkylene group having 1 to 10 carbon atoms", "linear or branched alkylene group having 2 to 4 carbon atoms", and "linear or branched alkyl group having 1 to 60 carbon atoms" may be the same as those in the descriptions of the general formulas (i) to (iii) above.

(Alkyl (Meth)Acrylate (x2-b))

[0147] Examples of the alkyl (meth)acrylate (x2-b) include methyl (meth)acrylate, ethyl (meth)acrylate, n-propyl (meth)acrylate, isopropyl (meth)acrylate, n-butyl (meth)acrylate, t-butyl (meth)acrylate, pentyl (meth)acrylate, hexyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, heptyl (meth)acrylate, 2-t-butylheptyl (meth)acrylate, octyl (meth)acrylate, and 3-isopropylheptyl (meth)acrylate.

[0148] The carbon number of the alkyl group of the alkyl (meth)acrylate (x2-b) is preferably 4 to 30, more preferably 4 to 24, and still more preferably 4 to 18.

[0149] The alkyl group may be a linear alkyl group or a branched alkyl group.

[0150] The content ratio of a structural unit (a) derived from the butyl (meth)acrylate to a structural unit (β) derived from the alkyl (meth)acrylate having an alkyl group having 12 to 20 carbon atoms [(α)/(β)] is preferably 7.00 or more, more preferably 8.50 or more, and still more preferably 10.00 or more, and is preferably 20 or less, in terms of a molar ratio.

[0151] The content of the structural unit (a) derived from the butyl (meth)acrylate is preferably 40 to 95 mol%, more preferably 50 to 90 mol%, and still more preferably 60 to 85 mol% based on the total amount (100 mol%) of structural units of the comb-shaped polymer.

[0152] The content of the structural unit (β) derived from the alkyl (meth)acrylate having an alkyl group having 12 to 20 carbon atoms is preferably 1 to 30 mol%, more preferably 3 to 25 mol%, and still more preferably 5 to 20 mol% based on the total amount (100 mol%) of structural units of the comb-shaped polymer.

(Nitrogen Atom-Containing Vinyl Monomer (x2-c))

[0153] Examples of the nitrogen atom-containing vinyl monomer (x2-c) include an amide group-containing vinyl monomer (x2-c1), a nitro group-containing monomer (x2-c2), a primary amino group-containing vinyl monomer (x2-c3), a secondary amino group-containing vinyl monomer (x2-c4), a tertiary amino group-containing vinyl monomer (x2-c5), and a nitrile group-containing vinyl monomer (x2-c6).

[0154] Examples of the amide group-containing vinyl monomer (x2-c1) include: (meth)acrylamide; monoalkylamino (meth)acrylamide, such as N-methyl (meth)acrylamide, N-ethyl (meth)acrylamide, N-isopropyl (meth)acrylamide, N-n-butyl (meth)acrylamide, and N-isobutyl (meth)acrylamide; monoalkylaminoalkyl (meth)acrylamide, such as N-methylaminoethyl (meth)acrylamide, N-ethylaminoethyl (meth)acrylamide, N-isopropylamino-n-butyl (meth)acrylamide, N-n-butylamino-n-butyl (meth)acrylamide, and N-isobutylamino-n-butyl (meth)acrylamide; dialkylamino (meth)acrylamide, such as N,N-dimethyl (meth)acrylamide, N,N-diethyl (meth)acrylamide, N,N-diisopropyl (meth)acrylamide, and N,N-di-n-butyl (meth)acrylamide; dialkylaminoalkyl (meth)acrylamide, such as N,N-dimethylaminoethyl (meth)acrylamide, N,N-diethylaminoethyl (meth)acrylamide, N,N-dimethylaminopropyl (meth)acrylamide, and N,N-di-n-butylaminobutyl (meth)acrylamide; and N-vinylcarboxylic acid amide, such as N-vinylformamide, N-vinylacetamide, N-vinyl-n-propionylamide, N-vinylisopropionylamide, and N-vinylhydroxyacetamide.

[0155] Examples of the nitro group-containing monomer (x2-c2) include nitroethylene and 3-nitro-1-propene.

[0156] Examples of the primary amino group-containing vinyl monomer (x2-c3) include: alkenylamine having an alkenyl group having 3 to 6 carbon atoms, such as (meth)allylamine and crotylamine; and aminoalkyl (meth)acrylate having an alkyl group having 2 to 6 carbon atoms, such as aminoethyl (meth)acrylate.

[0157] Examples of the secondary amino group-containing vinyl monomer (x2-c4) include: monoalkylaminoalkyl (meth)acrylate, such as t-butylaminoethyl (meth)acrylate and methylaminoethyl (meth)acrylate; and dialkenylamine having 6 to 12 carbon atoms, such as di(meth)allylamine.

[0158] Examples of the tertiary amino group-containing vinyl monomer (x2-c5) include: dialkylaminoalkyl (meth)acrylate, such as dimethylaminoethyl (meth)acrylate and diethylaminoethyl (meth)acrylate; alicyclic (meth)acrylate having a nitrogen atom, such as morpholinoethyl (meth)acrylate; and hydrochloride, sulfate, phosphate, or a lower alkyl (1 to 8 carbon atoms) monocarboxylic acid (e.g., acetic acid and propionic acid) salt thereof.

[0159] Examples of the nitrile group-containing vinyl monomer (x2-c6) include (meth) acrylonitrile.

[0160] In the comb-shaped polymer used in an embodiment of the present invention, it is preferable that the content of the structural unit derived from the nitrogen atom-containing vinyl monomer (x2-c) is as small as possible. Specifically, the content of the structural unit derived from the nitrogen atom-containing vinyl monomer (x2-c) is preferably less than 1.0 mol%, more preferably less than 0.5 mol%, still more preferably less than 0.1 mol%, yet still more preferably less than 0.01 mol%, and especially preferably 0 mol%, based on the total amount (100 mol%) of structural units of the comb-shaped polymer.

(Hydroxy Group-Containing Vinyl Monomer (x2-d))

[0161] Examples of the hydroxy group-containing vinyl monomer (x2-d) include a hydroxy group-containing vinyl monomer (x2-d1), and a polyoxyalkylene chain-containing vinyl monomer (x2-d2).

[0162] Examples of the hydroxy group-containing vinyl monomer (x2-d1) include: hydroxyalkyl (meth)acrylate having an alkyl group having 2 to 6 carbon atoms, such as 2-hydroxyethyl (meth)acrylate and 2- or 3-hydroxypropyl (meth)acrylate; mono- or di-hydroxyalkyl-substituted (meth)acrylamide having an alkyl group having 1 to 4 carbon atoms, such as N,N-dihydroxymethyl (meth)acrylamide, N,N-dihydroxypropyl (meth)acrylamide, and N,N-di-2-hydroxybutyl (meth)acrylamide; vinyl alcohol; alkenol having 3 to 12 carbon atoms, such as (meth)allyl alcohol, crotyl alcohol, isocrotyl alcohol, 1-octenol, and 1-undecenol; alkene monool or alkene diol having 4 to 12 carbon atoms, such as 1-buten-3-ol, 2-buten-1-ol, and 2-butene-1,4-diol; hydroxyalkyl alkenyl ether having an alkyl group having 1 to 6 carbon atoms and an alkenyl group having 3 to 10 carbon atoms, such as 2-hydroxyethyl propenyl ether; a compound in which an unsaturated group such as an alkenyl group or the above-described polymerizable functional group of the macromonomer (x1), etc., is introduced into polyhydric alcohol such as glycerin, pentaerythritol, sorbitol, sorbitan, diglycerin, sugars, and sucrose; and a compound in which an unsaturated group such as an alkenyl group or the above-described polymerizable functional group of the macromonomer (x1) is introduced into glyceric acid or glycerin fatty acid ester.

[0163] Of these, a hydroxy group-containing vinyl monomer having two or more hydroxy groups is preferable, and the compound in which the above-described unsaturated group is introduced into polyhydric alcohol or glyceric acid is more preferable.

[0164] Examples of the polyoxyalkylene chain-containing vinyl monomer (x2-d2) include polyoxyalkylene glycol (carbon number of the alkylene group: 2 to 4, degree of polymerization: 2 to 50), polyoxyalkylene polyol (polyoxyalkylene ether of the above-described polyhydric alcohol (carbon number of the alkylene group: 2 to 4, degree of polymerization: 2 to 100)), and a compound in which the above-described unsaturated group is introduced into a compound selected from alkyl (carbon number: 1 to 4) ethers of polyoxyalkylene glycol or polyoxyalkylene polyol.

[0165] Specifically, examples thereof include polyethylene glycol (Mn: 100 to 300) mono(meth)acrylate, polypropylene glycol (Mn: 130 to 500) mono(meth)acrylate, methoxypolyethylene glycol (Mn: 110 to 310) (meth)acrylate, lauryl alcohol ethylene oxide adduct (2 to 30 mols) (meth)acrylate, and mono(meth)acrylic acid polyoxyethylene (Mn: 150 to 230) sorbitan.

[0166] The content of the structural unit derived from the hydroxy group-containing vinyl monomer (x2-d) is preferably 0.1 to 30 mol%, more preferably 0.5 to 20 mol%, still more preferably 1 to 15 mol%, and yet still more preferably 3 to 10 mol% based on the total amount (100 mol%) of structural units of the comb-shaped polymer.

(Phosphorus Atom-Containing Monomer (x2-e))

[0167] Examples of the phosphorus atom-containing monomer (x2-e) include a phosphate ester group-containing monomer (x2-e1) and a phosphono group-containing monomer (x2-e2).

[0168] Examples of the phosphate ester group-containing monomer (x2-e1) include: (meth)acryloyloxyalkyl phosphate ester having an alkyl group having 2 to 4 carbon atoms, such as (meth)acryloyloxyethyl phosphate and (meth)acryloyloxyisopropyl phosphate; and alkenyl phosphate ester having an alkenyl group having 2 to 12 carbon atoms, such as vinyl phosphate, allyl phosphate, propenyl phosphate, isopropenyl phosphate, butenyl phosphate, pentenyl phosphate, octenyl phosphate, decenyl phosphate, and dodecenyl phosphate.

[0169] Examples of the phosphono group-containing monomer (x2-e2) include: (meth)acryloyloxyalkyl phosphonate having an alkyl group having 2 to 4 carbon atoms, such as (meth)acryloyloxyethyl phosphonate; and alkenyl phosphonate having an alkenyl group having 2 to 12 carbon atoms, such as vinyl phosphonate, allyl phosphonate, and octenyl phosphonate.

[0170] In the comb-shaped polymer used in an embodiment of the present invention, it is preferable that the content of the structural unit derived from the phosphorus atom-containing monomer (x2-e) is as small as possible.

[0171] Specifically, the content of the structural unit derived from the phosphorus atom-containing monomer (x2-e) is preferably less than 1.0 mol%, more preferably less than 0.5 mol%, still more preferably less than 0.1 mol%, yet still more preferably less than 0.01 mol%, and especially preferably 0 mol% based on the total amount (100 mol%) of structural units of the comb-shaped polymer.

(Aliphatic Hydrocarbon-Based Vinyl Monomer (x2-f))

[0172] Examples of the aliphatic hydrocarbon-based vinyl monomer (x2-f) include: alkene having 2 to 20 carbon atoms, such as ethylene, propylene, butene, isobutylene, pentene, heptene, diisobutylene, octene, dodecene, and octadecene; and alkadiene having 4 to 12 carbon atoms, such as butadiene, isoprene, 1,4-pentadiene, 1,6-heptadiene, and 1,7-octadiene.

[0173] The carbon number of the aliphatic hydrocarbon-based vinyl monomer (x2-f) is preferably 2 to 30, more preferably 2 to 20, and still more preferably 2 to 12.

(Alicyclic Hydrocarbon-Based Vinyl Monomer (x2-g))

[0174] Examples of the alicyclic hydrocarbon-based vinyl monomer (x2-g) include cyclohexene, (di)cyclopentadiene, pinene, limonene, and vinylcyclohexene, ethylidene bicycloheptene.

[0175] The carbon number of the alicyclic hydrocarbon-based vinyl monomer (x2-g) is preferably 3 to 30, more preferably 3 to 20, and still more preferably 3 to 12.

(Vinyl Esters (x2-h))

[0176] Examples of the vinyl esters (x2-h) include vinyl ester of a saturated fatty acid having 2 to 12 carbon atoms, such as vinyl acetate, vinyl propionate, vinyl butyrate, and vinyl octanoate.

(Vinyl Ethers (x2-i))

[0177] Examples of the vinyl ethers (x2-i) include alkyl vinyl ether having 1 to 12 carbon atoms, such as methyl vinyl ether, ethyl vinyl ether, propyl vinyl ether, butyl vinyl ether, and 2-ethylhexyl vinyl ether; and alkoxyalkyl vinyl ether having 1 to 12 carbon atoms, such as vinyl-2-methoxyethyl ether and vinyl-2-butoxyethyl ether.

(Vinyl Ketones (x2-j))

[0178] Examples of the vinyl ketones (x2-j) include alkyl vinyl ketone having 1 to 8 carbon atoms, such as methyl vinyl ketone and ethyl vinyl ketone.

(Epoxy Group-Containing Vinyl Monomer (x2-k))

[0179] Examples of the epoxy group-containing vinyl monomer (x2-k) include glycidyl (meth)acrylate and glycidyl (meth)allyl ether.

(Halogen Element-Containing Vinyl Monomer (x2-l))

[0180] Examples of the halogen element-containing vinyl monomer (x2-1) include vinyl chloride, vinyl bromide, vinylidene chloride, and (meth)allyl chloride.

(Ester of Unsaturated Polycarboxylic Acid (x2-m))

[0181] Examples of the ester of unsaturated polycarboxylic acid (x2-m) include alkyl ester of unsaturated polycarboxylic acid, cycloalkyl ester of unsaturated polycarboxylic acid, and aralkyl ester of unsaturated polycarboxylic acid; and examples of the unsaturated carboxylic acid include maleic acid, fumaric acid, and itaconic acid.

((Di)alkyl Fumarate (x2-n))

[0182] Examples of the (di)alkyl fumarate (x2-n) include monomethyl fumarate, dimethyl fumarate, monoethyl fumarate, diethyl fumarate, methylethyl fumarate, monobutyl fumarate, dibutyl fumarate, dipentyl fumarate, and dihexyl fumarate.

((Di)alkyl Maleate (x2-o))

[0183] Examples of the (di)alkyl maleate (x2-o) include monomethyl maleate, dimethyl maleate, monoethyl maleate, diethyl maleate, methylethyl maleate, monobutyl maleate, and dibutyl maleate.

(Aromatic Hydrocarbon-Based Vinyl Monomer (x2-p))

[0184] Examples of the aromatic hydrocarbon-based vinyl monomer (x2-p) include styrene, α-methylstyrene, α-ethylstyrene, vinyltoluene, 2,4-dimethylstyrene, 4-ethylstyrene, 4-isopropylstyrene, 4-butylstyrene, 4-phenylstyrene, 4-cyclohexylstyrene, 4-benzylstyrene, p-methylstyrene, monochlorostyrene, dichlorostyrene, tribromostyrene, tetrabromostyrene, 4-crotylbenzene, indene, and 2-vinylnaphthalene.

[0185] The carbon number of the aromatic hydrocarbon-based vinyl monomer (x2-p) is preferably 8 to 30, more preferably 8 to 20, and still more preferably 8 to 18.

[0186] In the comb-shaped polymer (B1-1) used in an embodiment of the present invention, it is preferable that the content of the structural unit derived from the aromatic hydrocarbon-based vinyl monomer (x2-p) is as small as possible.

[0187] Specifically, the content of the structural unit derived from the aromatic hydrocarbon-based vinyl monomer (x2-p) is preferably less than 1.0 mol%, more preferably less than 0.5 mol%, still more preferably less than 0.1 mol%, yet still more preferably less than 0.01 mol%, and especially preferably 0 mol%, based on the total amount (100 mol%) of structural units of the comb-shaped polymer.

<<Content Ratio of Resin Component (B1) Derived from Viscosity Index Improver (B) and First Olefin-Based Polymer (A1-1)>>

[0188] In the lubricating oil composition of the present invention, the content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is more than 0.001 in terms of a mass ratio.

[0189] [(B1)/(A1-1)] indicates the amount of the resin component (B1) derived from the viscosity index improver (B) with respect to the first olefin-based polymer (A1-1), and when the value of [(B1)/(A1-1)] is 0.001 or less, the oil film retainability of the lubricating oil composition is deteriorated.

[0190] Here, from the viewpoint of facilitating the production of the lubricating oil composition exhibiting the excellent oil film retainability, in the lubricating oil composition according to an embodiment of the present invention, [(B1)/(A1-1)] is preferably 0.002 or more, more preferably 0.003 or more, still more preferably 0.004 or more, and yet still more preferably 0.005 or more. Further, from the viewpoint of the shear stability, [(B1)/(A1-1)] is preferably 0.10 or less, more preferably 0.05 or less, and still more preferably 0.02 or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, [(B1)/(A1-1)] is preferably 0.002 to 0.10, more preferably 0.003 to 0.05, still more preferably 0.004 to 0.02, and yet still more preferably 0.005 to 0.02.

« Imide-Based Dispersant (C) »

[0191] The lubricating oil composition of the present invention contains the imide-based dispersant (C).

[0192] In the lubricating oil composition of the present invention, the content of nitrogen atoms derived from the imide-based dispersant (C) is 0.06% by mass or more based on the total amount of the lubricating oil composition.

[0193] When the content of the nitrogen atoms derived from the imide-based dispersant (C) is less than 0.06% by mass, the high-temperature cleanliness of the lubricating oil composition may not be ensured. Further, the oil film retainability may not be sufficiently ensured.

[0194] From the viewpoint of further improving the cleanliness at high temperature and the oil film retainability, in the lubricating oil composition according to an embodiment of the present invention, the content of the nitrogen atoms derived from the imide-based dispersant (C) is preferably 0.08% by mass or more, more preferably 0.10% by mass or more, and still more preferably 0.11% by mass or more. Further, the content is preferably 1.00% by mass or less, more preferably 0.50% by mass or less, and still more preferably 0.20% by mass or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the content is preferably 0.08% by mass to 1.00% by mass, more preferably 0.10% by mass to 0.50% by mass, and still more preferably 0.11% by mass to 0.20% by mass.

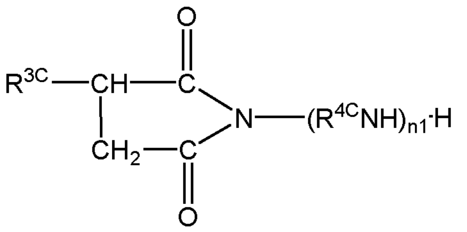
[0195] Further, in the lubricating oil composition according to an embodiment of the present invention, the content of the imide-based dispersant (C) may be adjusted such that the content of the nitrogen atoms derived from the imide-based dispersant (C) satisfies the ranges described above. The content of the imide-based dispersant (C) is preferably 1.0% by mass or more, more preferably 5.0% by mass or more, and still more preferably 7.5% by mass or more, based on the total amount of the lubricating oil composition. Further, the content is preferably 20.0% by mass or less, more preferably 15.0% by mass or less, and still more preferably 12.5% by mass or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the content is preferably 1.0% by mass to 20.0% by mass, more preferably 5.0% by mass to 15.0% by mass, and still more preferably 7.5% by mass to 12.5% by mass.

[0196] Examples of the imide-based dispersant (C) include one or more compounds selected from the group consisting of: succinic acid monoimide such as alkenyl succinic acid monoimide and alkyl succinic acid monoimide; a boron-modified product of succinic acid monoimide; succinic acid bisimide such as alkenyl succinic acid bisimide and alkyl succinic acid bisimide; and a boron-modified product of succinic acid bisimide.

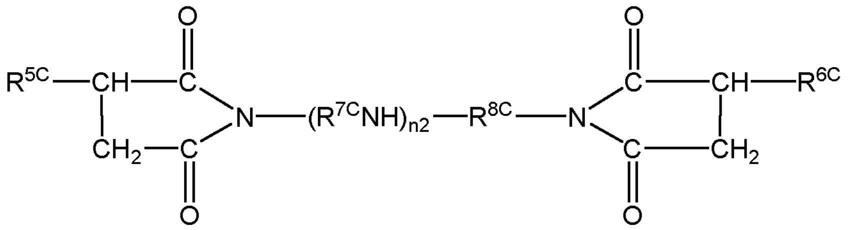
[0197] Of these, one or more selected from the group consisting of succinic acid monoimide (non-boron modified product) and succinic acid bisimide (non-boron modified product) are preferable.

[0198] The imide-based dispersant (C) may be used either alone or in combination of two or more thereof.

[0199] Examples of the alkenyl succinic acid monoimide or the alkyl succinic acid monoimide include a compound represented by the following general formula (c-1). Further, examples of the alkenyl succinic acid bisimide or the alkyl succinic acid bisimide include a compound represented by the following general formula (c-2).



(c-1)



(c-2)

[0200] In the general formulas (c-1) and (c-2), R^{3C}, R^{5C}, and R^{6C} are alkenyl groups or alkyl groups, and the mass average molecular weight (Mw) of each of R^{3C}, R^{5C}, and R^{6C} is preferably 500 to 3,000, and more preferably 1,000 to 3,000.

[0201] When the mass average molecular weight of each of R^{3C}, R^{5C}, and R^{6C} is 500 or more, the favorable solubility in the base oil (A) can be achieved. Further, when the mass average molecular weight is 3,000 or less, the effects of the present invention can more easily be achieved. R^{5C} and R^{6C} may be the same or different from each other.

[0202] Each of R^{4C}, R^{7C}, and R^{8C} is an alkylene group having 2 to 5 carbon atoms, and R^{7C} and R^{8C} may be the same or different from each other. The "n1" indicates an integer of 1 to 10, and "n2" indicates 0 or an integer of 1 to 10. Here, n1 is preferably 2 to 5, and more preferably 2 to 4. When n1 is 2 or more, the effects of the present invention can more easily be achieved. When n1 is 5 or less, the solubility in the base oil (A) becomes more favorable.

[0203] In the general formula (c-2), n2 is preferably 1 to 6, and more preferably 2 to 6. When n2 is 1 or more, the effects of the present invention can more easily be achieved. When n2 is 6 or less, the solubility in the base oil (A) becomes more favorable.

[0204] Examples of the alkenyl group that may be selected as R^{3C}, R^{5C}, and R^{6C} include a polybutenyl group, a polyisobutenyl group, and an ethylene-propylene copolymer, and preferably a polybutenyl group or a polyisobutenyl group. As the polybutenyl group, a mixture of 1-butene and isobutene or a polymer of high-purity isobutylene is preferably used.

[0205] Examples of the alkyl group that may be selected as R^{3C}, R^{5C}, and R^{6C} include ones obtained by hydrogenating a polybutenyl group, a polyisobutenyl group, or an ethylene-propylene copolymer, and preferably ones obtained by hydrogenating the polybutenyl group or the polyisobutenyl group.

[0206] The alkenyl succinic acid imide or alkyl succinic acid imide described above may be usually prepared by reacting alkenyl succinic anhydride obtained by a reaction between polyolefin and maleic anhydride, or alkyl succinic anhydride obtained by hydrogenating the alkenyl succinic anhydride, with polyamine. The monoimide or bisimide may be prepared by changing the ratio of the alkenyl succinic anhydride or the alkyl succinic anhydride to polyamine.

[0207] The alkenyl succinic acid imide or alkyl succinic acid imide described above may be a boron-modified product. The boron-modified product may be prepared by reacting, for example, boron-free alkenyl succinic acid monoimide or alkyl succinic acid monoimide, or alkenyl succinic acid bisimide or alkyl succinic acid bisimide, with a boron compound.

[0208] As the olefin monomer forming the polyolefin, for example, one or more selected from α-olefins having 2 to 8 carbon atoms may be used, and a mixture of isobutene and 1-butene may be preferably used.

[0209] Meanwhile, examples of polyamine include: single diamine such as ethylenediamine, propylenediamine, butylenediamine, and pentylenediamine; polyalkylene polyamine such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, di(methylethylene)triamine, dibutylenetriamine, tributylenetetramine, and pentapentylenehexamine; and piperazine derivative such as aminoethylpiperazine. The polyamine may be used either alone or in combination of two or more thereof.

[0210] Examples of the boron compound include boric acid, borate, and boric acid ester.

[0211] Examples of the boric acid include orthoboric acid, metaboric acid, and paraboric acid.

[0212] Examples of the borate include ammonium borate such as ammonium metaborate, ammonium tetraborate, ammonium pentaborate, and ammonium octaborate.

[0213] Examples of the boric acid ester include monomethyl borate, dimethyl borate, trimethyl borate, monoethyl borate, diethyl borate, triethyl borate, monopropyl borate, dipropyl borate, tripropyl borate, monobutyl borate, dibutyl borate, and tributyl borate.

<<Metal-Based Detergent (D)>>

[0214] The lubricating oil composition according to an embodiment of the present invention may contain a metal-based detergent (D).

[0215] When the lubricating oil composition according to an embodiment of the present invention contains the metal-based detergent (D), the high-temperature cleanliness of the lubricating oil composition can be further improved.

[0216] From the viewpoint of achieving the more favorable cleanliness at high temperature, and decreasing the content of sulfated ash to a low level, in the lubricating oil composition according to an embodiment of the present invention, the content of metal atoms derived from the metal-based detergent (D) is preferably 0.01% by mass to 0.20% by mass, more preferably 0.05% by mass to 0.18% by mass, and still more preferably 0.08% by mass to 0.15% by mass, based on the total amount of the lubricating oil composition.

[0217] Further, in the lubricating oil composition according to an embodiment of the present invention, the content of the metal-based detergent (D) may be adjusted such that the content of the metal atoms derived from the metal-based detergent (D) satisfies the ranges described above. The content of the metal-based detergent (D) is preferably 0.1% by mass to 10.0% by mass, more preferably 0.5% by mass to 5.0% by mass, and still more preferably 0.75% by mass to 2.0% by mass, based on the total amount of the lubricating oil composition.

[0218] Examples of the metal-based detergent (D) include an alkali metal-based detergent and an alkaline earth metal-based detergent, and especially, the alkaline earth metal-based detergent is preferable.

[0219] Further, examples of an alkaline earth metal constituting the alkaline earth metal-based detergent include magnesium (Mg), calcium (Ca), strontium (Sr), and barium (Ba), and especially, calcium (Ca) and magnesium (Mg) are preferable.

[0220] That is, the metal-based detergent (D) is preferably one or more selected from the group consisting of a calcium-based detergent (D1) and a magnesium-based detergent (D2).

[0221] Hereinafter, the calcium-based detergent (D1) and the magnesium-based detergent (D2) will be described in detail.

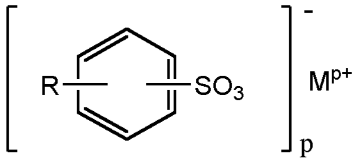
<Calcium-Based Detergent (D1)>

[0222] Examples of the calcium-based detergent (D1) include calcium salts such as calcium sulfonate, calcium phenate, and calcium salicylate.

[0223] Among the salts, calcium phenate and calcium salicylate are preferable, and calcium salicylate is more preferable, from the viewpoint of achieving the more favorable cleanliness at high temperature.

[0224] The calcium sulfonate is preferably a compound of metal sulfonate represented by the following general formula (d1-1) in which M is a calcium atom. The calcium phenate is preferably a compound of metal phenate represented by the following general formula (d1-2) in which M' is a calcium atom. The calcium salicylate is preferably a compound of metal salicylate represented by the following general formula (d1-3) in which M is a calcium atom.

[0225] The calcium-based detergent (D1) may be used either alone or in combination of two or more thereof.



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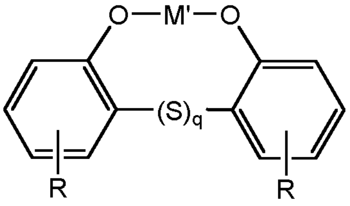
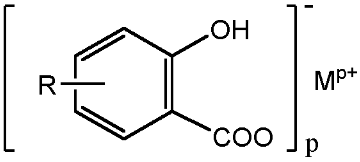


(d1-2)



(d1-3)

[0226] In the general formulas (d1-1) to (d1-3) above, M is a metal atom selected from an alkali metal and an alkaline earth metal, and M' is an alkaline earth metal. The "p" is the valence of M, which is 1 or 2. The "R" is a hydrogen atom or a hydrocarbon group having 1 to 18 carbon atoms. The "q" is an integer of 0 or more, and preferably an integer of 0 to 3.

[0227] Examples of the hydrocarbon group that may be selected as R include an alkyl group having 1 to 18 carbon atoms, an alkenyl group having 1 to 18 carbon atoms, a cycloalkyl group having 3 to 18 ring carbon atoms, and an aryl group having 6 to 18 ring carbon atoms, an alkylaryl group having 7 to 18 carbon atoms, and an arylalkyl group having 7 to 18 carbon atoms.

[0228] The calcium-based detergent (D1) may be neutral, basic, or overbased, and is preferably basic or overbased and more preferably overbased, from the viewpoint of further improving a base number maintaining property.

[0229] In this specification, a basic or overbased metal-based detergent indicates a detergent obtained through a reaction between a metal and an acidic organic compound and containing the metal in an excessive amount higher than the stoichiometric amount necessary for neutralizing the metal and the acidic organic compound. That is, when a "metal ratio" refers to a total chemical equivalent of a metal in a metal-based detergent to a chemical equivalent of a metal in a metal salt (neutral salt) obtained by reacting a metal and an acidic organic compound according to the stoichiometric amount necessary for neutralizing the metal and the acidic organic compound, the metal ratio of the basic or overbased metal-based detergent is higher than 1. The metal ratio of the basic or overbased metal-based detergent used in the present embodiment is preferably more than 1.3, more preferably 5 to 30, and still more preferably 7 to 22. A specific example of the basic or overbased metal-based detergent may be a compound including one or more selected from the group consisting of the above-described metal salicylate, metal phenate, and metal sulfonate, and containing a metal in an excessive amount.

[0230] In this specification, the "neutral" refers to a base number of less than 50 mgKOH/g measured by a measurement method to be described later, the "basic" refers to a base number of 50 mgKOH/g or more and less than 150 mgKOH/g, and the "overbased" refers to a base number of 150 mgKOH/g or more.

[0231] The base number of the calcium-based detergent (D1) is preferably 5 mgKOH/g or more, more preferably 100 mgKOH/g or more, still more preferably 150 mgKOH/g or more, and yet still more preferably 200 mgKOH/g or more, and is preferably 500 mgKOH/g or less, more preferably 450 mgKOH/g or less, and still more preferably 400 mgKOH/g or less.

[0232] In this specification, the "base number" of the metal-based detergent (D) refers to a base number measured by a perchloric acid method in conformity with JIS K 2501:2003.

[0233] From the viewpoint of achieving the more favorable cleanliness at high temperature, and decreasing the content of sulfated ash to a low level, in the lubricating oil composition according to an embodiment of the present invention, the content of calcium atoms derived from the metal-based detergent (D1) is preferably 0.01% by mass to 0.75% by mass, more preferably 0.02% by mass to 0.30% by mass, and still more preferably 0.05% by mass to 0.15% by mass, based on the total amount of the lubricating oil composition.

[0234] Further, in the lubricating oil composition according to an embodiment of the present invention, the content of the calcium-based detergent (D1) may be adjusted such that the content of the calcium atoms derived from the calcium-based detergent (D1) satisfies the ranges described above. The content of the calcium-based detergent (D1) is preferably 0.01% by mass to 10.0% by mass, more preferably 0.10% by mass to 5.0% by mass, and still more preferably 0.80% by mass to 2.00% by mass, based on the total amount of the lubricating oil composition.

<<Magnesium-Based Detergent (D2)>

[0235] Examples of the magnesium-based detergent (D2) include magnesium salts such as magnesium sulfonate, magnesium phenate, and magnesium salicylate.

[0236] Among the salts, magnesium sulfonate is preferable, from the viewpoint of achieving the more favorable cleanliness at high temperature.

[0237] The magnesium sulfonate is preferably a compound of metal sulfonate represented by the general formula (d1-1) above in which M is a magnesium atom. The magnesium phenate is preferably a compound of metal phenate represented by the general formula (d1-2) above in which M' is a magnesium atom. The magnesium salicylate is preferably a compound of metal salicylate represented by the general formula (d1-3) above in which M is a magnesium atom. The magnesium-based detergent (D2) may be used either alone or in combination of two or more thereof.

[0238] The magnesium-based detergent (D2) may be neutral, basic, or overbased, and is preferably basic or overbased from the viewpoint of the cleanliness.

[0239] The base number of the magnesium-based detergent (D2) is preferably 5 mgKOH/g or more, more preferably 100 mgKOH/g or more, still more preferably 150 mgKOH/g or more, and yet still more preferably 200 mgKOH/g or more, and is preferably 500 mgKOH/g or less, more preferably 450 mgKOH/g or less, and still more preferably 400 mgKOH/g or less.

[0240] From the viewpoint of achieving the more favorable cleanliness at high temperature, and decreasing the content of sulfated ash to a low level, in the lubricating oil composition according to an embodiment of the present invention, the content of magnesium atoms derived from the magnesium-based detergent (D2) is preferably 0.001% by mass to 0.1% by mass, more preferably 0.010% by mass to 0.050% by mass, and still more preferably 0.015% by mass to 0.025% by mass, based on the total amount of the lubricating oil composition.

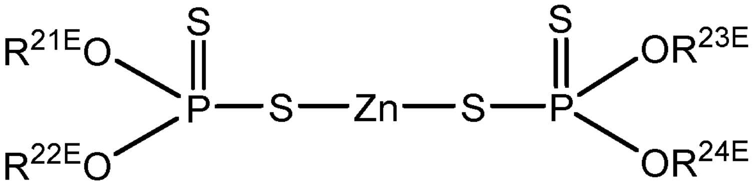
[0241] Further, in the lubricating oil composition according to an embodiment of the present invention, the content of the magnesium-based detergent (D2) may be adjusted such that the content of the magnesium atoms derived from the magnesium-based detergent (D2) satisfies the ranges described above. The content of the magnesium-based detergent (D2) is preferably 0.001% by mass to 2.000% by mass, more preferably 0.005% by mass to 1.000% by mass, and still more preferably 0.01% by mass to 0.300% by mass, based on the total amount of the lubricating oil composition.

<<Zinc Dithiophosphate (E)>>

[0242] The lubricating oil composition according to an embodiment of the present invention may contain zinc dithiophosphate (E).

[0243] When the lubricating oil composition according to an embodiment of the present invention contains the zinc dithiophosphate (E), the wear resistance of the lubricating oil composition can be further improved.

[0244] The zinc dithiophosphate (E) used in the lubricating oil composition according to an embodiment of the present invention may be preferably one represented by the following general formula (e-1).



(e-1)

[0245] In the general formula (e-1), each of R^{21E} to R^{24E} independently represents a hydrocarbon group. The hydrocarbon group is not particularly limited as long as the hydrocarbon group is a monovalent hydrocarbon group. For example, from the viewpoint of improving the oxidation stability, an alkyl group, an alkenyl group, a cycloalkyl group, and an aryl group are preferable, the alkyl group and the aryl group are more preferable, and the alkyl group is still more preferable. That is, as the zinc dithiophosphate used in an embodiment of the present invention, zinc dialkyldithiophosphate is preferable.

[0246] The alkyl group and the alkenyl group that may be selected as R^{21E} to R^{24E} may be linear or branched, and are preferably primary or secondary from the viewpoint of achieving the excellent oxidation stability, and especially, a primary alkyl group and a secondary alkyl group are preferable. That is, as the zinc dialkyl dithiophosphate, primary zinc dialkyl dithiophosphate and secondary zinc dialkyl dithiophosphate are preferable.

[0247] Further, when the monovalent hydrocarbon group is the alkyl group, the carbon number of the hydrocarbon group that may be selected as R^{21E} to R^{24E} is preferably 1 or more, more preferably 2 or more, and still more preferably 3 or more, and is preferably 24 or less, more preferably 18 or less, and still more preferably 12 or less as the upper limit thereof. When the monovalent hydrocarbon is the alkenyl group, the carbon number of the hydrocaron group is preferably 2 or more and more preferably 3 or more, and is preferably 24 or less, more preferably 18 or less, and still more preferably 12 or less as the upper limit thereof.

[0248] The cycloalkyl group and the aryl group that may be selected as R^{21E} to R^{24E} may be each a polycyclic group such as a decalyl group or a naphthyl group. When the monovalent hydrocarbon group is the cycloalkyl group, the carbon number of the hydrocarbon group that may be selected as R^{21E} to R^{24E} is preferably 5 or more, and is preferably 20 or less as the upper limit thereof. When the monovalent hydrocarbon is the aryl group, the carbon number is preferably 6 or more, and is preferably 20 or less as the upper limit thereof.

[0249] The monovalent hydrocarbon group may be partially substituted with a group containing oxygen atoms and/or nitrogen atoms such as a hydroxyl group, a carboxy group, an amino group, an amide group, a nitro group, or a cyano group, or may be partially substituted with nitrogen atoms, oxygen atoms, or halogen atoms, and when the monovalent hydrocarbon group is the cycloalkyl group or the aryl group, the monovalent hydrocarbon group may further have a substituent such as an alkyl group or an alkenyl group.

[0250] From the viewpoint of further improving the wear resistance of the lubricating oil composition, and reducing the amount of phosphorus in the lubricating oil composition to suppress the poisoning of an exhaust gas purification catalyst provided in an exhaust gas purifying apparatus, in the lubricating oil composition according to an embodiment of the present invention, the content of phosphorus atoms derived from the zinc dithiophosphate (E) is preferably 0.005% by mass to 0.200% by mass, more preferably 0.010% by mass to 0.150% by mass, and still more preferably 0.05% by mass to 0.100% by mass, based on the total amount of the lubricating oil composition.

[0251] From the same viewpoint, the content of zinc atoms derived from the zinc dithiophosphate (E) is preferably 0.005% by mass to 0.200% by mass, more preferably 0.10% by mass to 0.150% by mass, and still more preferably 0.06% by mass to 0.110% by mass, based on the total amount of the lubricating oil composition.

[0252] Further, in the lubricating oil composition according to an embodiment of the present invention, the content of the zinc dithiophosphate (E) may be adjusted such that the contents of the phosphorus atoms and the zinc atoms derived from the zinc dithiophosphate (E) satisfy the ranges described above. The content of the zinc dithiophosphate (E) is preferably 0.10% by mass to 5.00% by mass, more preferably 0.50% by mass to 2.50% by mass, and still more preferably 0.75% by mass to 1.25% by mass, based on the total amount of the lubricating oil composition.

«Other Additives for Lubricating Oil»

[0253] The lubricating oil composition according to an embodiment of the present invention may contain additives for the lubricating oil (hereinafter, also simply referred to as "lubricating oil additives") other than the above-described components, as necessary, as long as the effects of the present invention are not impaired.

[0254] Examples of the lubricating oil additives include an antioxidant, an extreme pressure agent, a friction modifier, an anti-foaming agent, a rust inhibitor, a corrosion inhibitor, and a metal deactivator. Further, an anti-wear agent other than the zinc dithiophosphate (E) may be added.

[0255] The lubricating oil additive may be used either alone or in combination of two or more thereof.

[0256] The content of each lubricating oil additive may be appropriately adjusted within the scope that does not impair the effects of the present invention, and is usually 0.001% by mass or more, preferably 0.005% by mass or more, and more preferably 0.01% by mass or more, and is preferably 30% by mass or less, more preferably 27% by mass or less, and still more preferably 24% by mass or less, based on the total amount of the lubricating oil composition.

[0257] In the lubricating oil composition according to an embodiment of the present invention, the total content of the lubricating oil additives is preferably 5% by mass or more, more preferably 10% by mass or more, and still more preferably 15% by mass or more, and is preferably 35% by mass or less, more preferably 30% by mass or less, still more preferably 27% by mass or less, and yet still more preferably 25% by mass or less, based on the total amount (100% by mass) of the lubricating oil composition.

<Antioxidant>

[0258] As the antioxidant, any known antioxidant that has been used as an antioxidant of a lubricating oil in the prior art may be appropriately selected and used, and for example, an amine-based antioxidant or a phenol-based antioxidant may be used.

[0259] The antioxidant may be used either alone or in combination of two or more thereof.

<Extreme Pressure Agent>

[0260] Examples of the extreme pressure agent include a sulfur-based extreme pressure agent such as sulfides, sulfoxides, sulfones, and thiophosphinates, a halogen-based extreme pressure agent such as chlorinated hydrocarbon, and an organic metal-based extreme pressure agent.

[0261] The extreme pressure agent may be used either alone or in combination of two or more thereof.

<Friction Modifier>

[0262] Examples of the friction modifier include: an ash-free friction modifier having at least one alkyl or alkenyl group having 6 to 30 carbon atoms in its molecule, such as aliphatic amine, fatty acid ester, fatty acid amide, fatty acid, aliphatic alcohol, and aliphatic ether; oils and fats; amine; amide; sulfide ester; phosphoric acid ester; phosphorous acid ester; and phosphoric acid ester amine salt.

[0263] The friction modifier may be used either alone or in combination of two or more thereof.

<Anti-Foaming Agent>

[0264] Examples of the anti-foaming agent include silicone oil, fluorosilicone oil, and fluoroalkyl ether.

[0265] The anti-foaming agent may be used either alone or in combination of two or more thereof.

<Rust Inhibitor>

[0266] Examples of the rust inhibitor include fatty acid, alkenyl succinic acid half ester, a fatty acid soap, alkyl sulfonate, polyhydric alcohol fatty acid ester, fatty acid amine, oxidized paraffin, and alkyl polyoxyethylene ether.

[0267] The rust inhibitor may be used either alone or in combination of two or more thereof.

<Corrosion Inhibitor and Metal Deactivator>

[0268] Examples of the corrosion inhibitor and 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.

[0269] The corrosion inhibitor or metal deactivator may be used either alone or in combination of two or more thereof.

<Anti-Wear Agent Other than Zinc Dithiophosphate (E)>

[0270] Examples of the anti-wear agent include: a sulfur-containing compound, such as zinc phosphate other than the zinc dithiophosphate (E), zinc dithiocarbamate, disulfides, olefin sulfides, oil and fat sulfides, sulfide esters, thiocarbonates, thiocarbamates, and polysulfides; a phosphorus-containing compound, such as phosphorous acid esters, phosphoric acid esters, phosphonic acid esters, and amine salts or metal salts thereof; a sulfur and phosphorus-containing anti-wear agent, such as thiophosphorous acid esters, thiophosphoric acid esters, thiophosphonic acid esters, and amine salts or metal salts thereof.

[0271] The anti-wear agent may be used either alone or in combination of two or more thereof.

<Molybdenum-Based Compound>

[0272] The lubricating oil composition according to an embodiment of the present invention may contain a molybdenum-based compound, and it is preferable that the content of the molybdenum-based compound is small. The lubricating oil composition according to an embodiment of the present invention exhibits the excellent wear resistance, even though the lubricating oil composition does not contain the molybdenum-based compound. Accordingly, the excellent effect may be achieved even without adding the molybdenum-based compound which may deteriorate the cleanliness at high temperature.

[0273] The content of Mo atoms derived from the molybdenum-based compound is preferably less than 0.10% by mass, more preferably less than 0.05% by mass, and still more preferably less than 0.04% by mass, based on the total amount of the lubricating oil composition, and the absence of the molybdenum-based compound is yet still more preferable.

[0274] Examples of the molybdenum-based compound include a 2-nuclear organic molybdenum compound such as 2-nuclear molybdenum dithiocarbamate; and a 3-nuclear organic molybdenum compound.

<Anti-Mist Agent>

[0275] The lubricating oil composition according to an embodiment of the present invention may contain an anti-mist agent, and it is preferable that the content of the anti-mist agent is small.

[0276] The content of the anti-mist agent is preferably less than 0.01% by mass, and more preferably less than 0.001% by mass, based on the total amount of the lubricating oil composition, and the absence of the anti-mist agent is still more preferable.

[0277] As the anti-mist agent, a hydrocarbon-based polymer compound such as polyisobutylene or an ethylene-propylene copolymer may be used. The number average molecular weight of the polymer compound is preferably 100,000 to 3,000,000, and more preferably 200,000 to 2,000,000.

[Physical Properties of Lubricating Oil Composition]

<100°C Kinematic Viscosity>

[0278] The 100°C kinetic viscosity of the lubricating oil composition of the present invention is 5.0 mm^2/s or more and less than 7.1 mm^2/s.

[0279] When the 100°C kinematic viscosity is less than 5.0 mm^2/s, it becomes difficult to retain the oil film, and a NOACK evaporation loss may easily increase. Further, when the 100°C kinematic viscosity is 7.1 mm^2/s or more, the fuel consumption reducing performance is deteriorated.

[0280] From this viewpoint, the 100°C kinematic viscosity of the lubricating oil composition according to an embodiment of the present invention is preferably 5.1 mm^2/s or more, more preferably 5.2 mm^2/s or more, and still more preferably 5.3 mm^2/s or more. Further, the 100°C kinematic viscosity is preferably 6.8 mm^2/s or less, more preferably 6.6 mm^2/s or less, and still more preferably 6.4 mm^2/s or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the 100°C kinematic viscosity is preferably 5.1 mm^2/s or more and 6.8 mm^2/s or less, more preferably 5.2 mm^2/s or more and 6.6 mm^2/s or less, and still more preferably 5.3 mm^2/s or more and 6.4 mm^2/s or less.

[0281] In this specification, the 100°C kinematic viscosity of the lubricating oil composition is a value measured in conformity with JIS K2283:2000.

<HTHS Viscosity at 150°C>

[0282] It is preferable that the lubricating oil composition according to an embodiment of the present invention has an HTHS (high-temperature high-shear) viscosity of 2.0 mPa·s or more and less than 2.3 mPa·s at 150°C.

[0283] When the HTHS viscosity at 150°C is 2.0 mPa·s or more, the oil film can easily be retained. Further, when the HTHS viscosity at 150°C is less than 2.3 mPa·s, the favorable fuel consumption reducing performance can be achieved.

[0284] From this viewpoint, the 50°C HTHS viscosity of the lubricating oil composition according to an embodiment of the present invention is more preferably 2.0 mPa·s or more and 2.2 mPa·s or less.

[0285] In this specification, the HTHS viscosity at 150°C is a value measured in conformity with ASTM D4683, using a TBS (tapered bearing simulator) high-temperature viscometer, under conditions of a temperature condition of 150°C and a shear rate of $10^6/s$.

<40°C Kinematic Viscosity>

[0286] It is preferable that the 40°C kinematic viscosity of the lubricating oil composition according to an embodiment of the present invention is 15.0 mm^2/s to 30.0 mm^2/s.

[0287] When the 40°C kinematic viscosity is 15.0 mm^2/s or more, the oil film can easily be retained, and the NOACK evaporation loss can easily be suppressed. Further, when the 40°C kinematic viscosity is 30 mm^2/s or less, the favorable fuel consumption reducing performance can be achieved.

[0288] From this viewpoint, the 40°C kinematic viscosity of the lubricating oil composition according to an embodiment of the present invention is more preferably 18.0 mm^2/s to 29.0 mm^2/s, still more preferably 20.0 mm^2/s to 28.0 mm^2/s, and yet still more preferably 21.0 mm^2/s to 27.0 mm^2/s.

[0289] In this specification, the 40°C kinematic viscosity of the lubricating oil composition is a value measured in conformity with JIS K2283:2000.

<Viscosity Index>

[0290] The viscosity index of the lubricating oil composition according to an embodiment of the present invention is preferably 150 or more, more preferably 160 or more, and still more preferably 170 or more. Further, the viscosity index is preferably 230 or less, more preferably 220 or less, and still more preferably 210 or less. The upper and lower limit values of these numerical ranges may be arbitrarily combined. Specifically, the viscosity index is preferably 150 to 230, more preferably 160 to 220, and still more preferably 170 to 210.

[0291] In this specification, the viscosity index of the lubricating oil composition is a value measured in conformity with JIS K2283:2000.

<NOACK Evaporation Loss>

[0292] The NOACK evaporation loss (250°C; 1 hour) of the lubricating oil composition according to an embodiment of the present invention is less than 23% by mass. When the NOACK evaporation loss is 23% by mass or more, the viscosity of the lubricating oil composition increases, which deteriorates the fuel consumption reducing performance.

[0293] From this viewpoint, the NOACK evaporation loss of the lubricating oil composition according to an embodiment of the present invention is preferably 22% by mass or less, more preferably 21% by mass or less, and still more preferably 20% by mass or less. Further, the NOACK evaporation loss is usually 0.1% by mass or more.

[0294] In this specification, the NOACK evaporation loss is a value measured under conditions of 250°C and 1 hour in conformity with JPI-5S-41-2004.

<Aniline Point>

[0295] The aniline point of the lubricating oil composition of the present invention is 95°C or higher.

[0296] When the aniline point of the lubricating oil composition is less than 95°C, the rubber material may swell or harden.

[0297] Here, from the viewpoint of further improving the compatibility with the rubber material without causing the swelling or hardening of the rubber material, the aniline point is preferably 100°C or higher, and more preferably 110°C or higher.

[0298] In this specification, the aniline point is a value measured in conformity with JIS K 2256:2013.

<Cleanliness at High Temperature>

[0299] The lubricating oil composition of the present invention exhibits the excellent cleanliness at high temperature.

[0300] Specifically, the evaluation score of a hot tube test conducted according to a method described in Examples to be described later is preferably 2.5 or more.

<Oil Film Retainability>

[0301] The lubricating oil composition of the present invention exhibits the excellent oil film retainability. Specifically, the thickness of the oil film measured according to a method described in Examples to be described later is preferably 60 nm or more.

<Content of Molybdenum Atoms>

[0302] In the lubricating oil composition according to an embodiment of the present invention, the content of molybdenum (Mo) atoms is preferably less than 0.10% by mass, more preferably less than 0.05% by mass, still more preferably less than 0.04% by mass, and yet still more preferably less than 0.02% by mass, based on the total amount of the lubricating oil composition, and the absence of the molybdenum (Mo) atoms is especially preferable.

[0303] The content of the molybdenum atoms may be measured in conformity with JIS-5S-38-03.

[Method for Producing Lubricating Oil Composition]

[0304] The method for producing the lubricating oil composition of the present invention is not particularly limited.

[0305] For example, the method for producing the lubricating oil composition according to an embodiment of the present invention relates to a method for producing a lubricating oil composition, comprising: mixing a base oil (A) containing an olefin-based polymer (A1), a viscosity index improver (B), and an imide-based dispersant (C), wherein a first olefin-based polymer (A1-1) having a kinematic viscosity at 100°C of 3.0 mm^2/s or more is contained as the olefin-based polymer (A1), and a content of the first olefin-based polymer (A1-1) is 30% by mass or more based on a total amount of the base oil (A),

a second olefin-based polymer (A1-2) having a kinematic viscosity at 100°C of less than 3.0 mm^2/s is not contained

as the olefin-based polymer (A1), or is contained in a content of less than 18.5% by mass based on the total amount of the base oil (A),
a content of a resin component (B1) derived from the viscosity index improver (B) is 0.01% by mass or more based on a total amount of the lubricating oil composition,
a content of nitrogen atoms derived from the imide-based dispersant (C) is 0.06% by mass or more based on the total amount of the lubricating oil composition,
a content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is more than 0.001 in terms of a mass ratio,
the kinematic viscosity at 100°C is 5.0 mm^2/s or more and less than 7.1 mm^2/s, and
an aniline point is 95°C or higher.

[0306] While the method of mixing the above-described components is not particularly limited, for example, the viscosity index improver (B) and the imide-based dispersant (C) may be mixed with the base oil (A) containing the olefin polymer (A1). The viscosity index improver (B) and the imide-based dispersant (C) may be simultaneously or separately mixed with the base oil (A) containing the olefin-based polymer (A1). The same applies to the mixing of components other than the viscosity index improver (B) and the imide-based dispersant (C). Each component may be mixed in the state of a solution (dispersion) obtained by adding a diluent oil or the like to the component. It is preferable that after the mixing of each component, the resulting solution is stirred and uniformly dispersed by a known method.

[Application of Lubricating Oil Composition]

[0307] The lubricating oil composition according to an embodiment of the present invention may be preferably used as a lubricating oil composition for an internal combustion engine such as a gasoline engine, a diesel engine, or a gas engine of an automobile such as a two-wheeled vehicle or a four-wheeled vehicle, a generator, and a ship, and in particular, may be preferably used as a lubricating oil composition used in an environment with a high thermal load, e.g., an internal combustion engine such as an engine equipped with a forced-induction device such as a turbocharger.
[0308] Further, the lubricating oil composition according to an embodiment of the present invention may be very preferably used to be filled in the internal combustion engine, in particular, an internal combustion engine equipped with a forced-induction device (forced-induction-device-equipped engine), and lubricate each part related to the internal combustion engine.
[0309] Thus, an embodiment of the present invention provides a method of lubricating an internal combustion engine by using the lubricating oil composition described above. Further, an embodiment of the present invention provides a method of lubricating the internal combustion engine equipped with a forced-induction device (forced-induction-device-equipped engine) by using the lubricating oil composition.

[Embodiment of Present Invention]

[0310] An embodiment of the present invention provides the following [1] to [11]:

[1] A lubricating oil composition comprising a base oil (A) containing an olefin-based polymer (A1), a viscosity index improver (B), and an imide-based dispersant (C),

wherein a first olefin-based polymer (A1-1) having a kinematic viscosity at 100°C of 3.0 mm^2/s or more is contained as the olefin-based polymer (A1), and a content of the first olefin-based polymer (A1-1) is 30% by mass or more based on a total amount of the base oil (A),
a second olefin-based polymer (A1-2) having a kinematic viscosity at 100°C of less than 3.0 mm^2/s is not contained as the olefin-based polymer (A1), or is contained in a content of less than 18.5% by mass based on the total amount of the base oil (A),
a content of a resin component (B1) derived from the viscosity index improver (B) is 0.01% by mass or more based on a total amount of the lubricating oil composition,
a content of nitrogen atoms derived from the imide-based dispersant (C) is 0.06% by mass or more based on the total amount of the lubricating oil composition,
a content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is more than 0.001 in terms of a mass ratio,
the kinematic viscosity at 100°C is 5.0 mm^2/s or more and less than 7.1 mm^2/s, and
an aniline point is 95°C or higher.

[2] The lubricating oil composition according to [1] above, wherein the base oil (A) contains one or more selected

from the group consisting of a mineral oil (A2), and a synthetic oil (A3) other than the first olefin-based polymer (A1-1) and the second olefin-based polymer (A1-2).

[3] The lubricating oil composition according to [2] above, wherein a content of the mineral oil (A2) is 50% by mass or less based on the total amount of the base oil (A).

[4] The lubricating oil composition according to any one of [1] to [3] above, wherein a high-temperature high-shear (HTHS) viscosity at 150°C is 2.0 mPa·s or more and less than 2.3 mPa·s.

[5] The lubricating oil composition according to any one of [1] to [4] above, wherein a mass average molecular weight (Mw) of the resin component (B1) is 200,000 or more.

[6] The lubricating oil composition according to any one of [1] to [5] above, further comprising a metal-based detergent (D).

[7] The lubricating oil composition according to any one of [1] to [6] above, further comprising zinc dithiophosphate (E).

[8] The lubricating oil composition according to any one of [1] to [7] above, which is used in an internal combustion engine.

[9] The lubricating oil composition according to any one of [1] to [7] above, which is used in an internal combustion engine equipped with a forced-induction device.

[10] A method for lubricating an internal combustion engine using the lubricating oil composition according to any one of [1] to [7] above.

[11] The method according to [10] above, wherein the internal combustion engine is an internal combustion engine equipped with a forced-induction device.

Examples

[0311] The present invention will be specifically described by reference to the following Examples, but is not limited to the Examples.

[Method of Measuring Various Physical Properties]

[0312] Each raw material used in each Example and each Comparative Example, and each property and each state of the lubricating oil composition of each Example and each Comparative Example were measured according to the following procedures.

[0313]

(1) 40°C Kinematic Viscosity and 100°C Kinematic Viscosity

The 40°C kinematic viscosity and the 100°C kinematic viscosity of the base oil and the lubricating oil composition were measured in conformity with JIS K2283:2000.

(2) Viscosity Index

The viscosity indexes of the base oil and the lubricating oil composition were calculated from the measured values of the 40°C kinematic viscosity and the 100°C kinematic viscosity measured in conformity with JIS K2283:2000.

(3) HTHS Viscosity at 150°C

The HTHS viscosity at 150°C of the lubricating oil composition was measured in conformity with ASTM D4683, using a TBS (tapered bearing simulator) viscometer, under conditions of a temperature of 150°C and a shear rate of 10^6/s.

(4) NOACK Evaporation Loss

The NOACK evaporation loss of the lubricating oil composition was measured in conformity with JPI-5S-41-2004 under conditions of 250°C of 1 hour.

(5) Aniline Point

The aniline point of the lubricating oil composition was measured in conformity with JIS K 2256:2013.

(6) Mass Average Molecular Weight (Mw) and Number Average Molecular Weight (Mn)

The measurement was performed by using a gel permeation chromatography device ("1260 Type HPLC" manufactured by Agilent) under the following conditions, and the values measured according to the standard polystyrene conversion were adopted.

(Measurement Conditions)

[0314]

- Column: Two "Shodex LF404" columns connected in series
- Column temperature: 35°C
- Developing solvent: Chloroform

- Flow rate: 0.3 mL/min

[Examples 1 to 4 and Comparative Examples 1 to 6]

[0315] Abase oil (A), a viscosity index improver (B), an imide-based dispersant (C), and various additives described herein below were sufficiently mixed with the mixing ratio described in Table 1 (unit: mass%), thereby preparing the lubricating oil compositions of Examples 1 to 4 and Comparative Examples 1 to 6, respectively.

[0316] Details of the base oil (A), the viscosity index improver (B), the imide-based dispersant (C), and the various additives used for the preparation of the lubricating oil compositions of Examples 1 to 4 and Comparative Examples 1 to 6 are described herein below.

[0317] The mixing amount of the viscosity index improver (B) described in Table 1 is a mixing amount of an active component (the resin component (B1)) in which a diluent oil is eliminated.

<Base Oil (A)>

[0318]

(First Olefin-Based Polymer (A1-1)-1)

Olefin-based polymer obtained in Production Example 1 to be described later
40°C kinematic viscosity: 13.61 mm^2/s, 100°C kinematic viscosity: 3.42 mm^2/s, viscosity index: 129

(First Olefin-Based Polymer (A1-1)-2)

Product name "Durasyn 133" manufactured by Ineos
40°C kinematic viscosity: 13.41 mm^2/s, 100°C kinematic viscosity: 3.36 mm^2/s, viscosity index: 125

(Second Olefin-Based Polymer (A1-2)-1)

Product name "Durasyn 163" manufactured by Ineos
40°C kinematic viscosity: 5.10 mm^2/s, 100°C kinematic viscosity: 1.80 mm^2/s

(Second Olefin-Based Polymer (A1-2)-2)

Poly-α-olefin oligomer synthesized from 1-decene which is a raw material monomer, by using a BF_3 catalyst
40°C kinematic viscosity: 5 mm^2/s, 100°C kinematic viscosity: 1.7 mm^2/s (Mineral Oil (A2)-1)
Mineral oil classified into Group III of the API category
40°C kinematic viscosity: 19 mm^2/s, 100°C kinematic viscosity: 4.2 mm^2/s, viscosity index: 126

(Mineral Oil (A2)-2)

Mineral oil classified into Group II of the API category
40°C kinematic viscosity: 12 mm^2/s, 100°C kinematic viscosity: 3.0 mm^2/s, viscosity index: 106

(Ester-Based Oil (A3-1)

Dioctyl sebacate
40°C kinematic viscosity: 12 mm^2/s, 100°C kinematic viscosity: 3.2 mm^2/s, viscosity index: 151

<Production Example 1: Production of First Olefin-Based Polymer (A1-1)-1)>

(1) Polymerization of 1-Decene

[0319] In a three-necked flask having an internal volume of 5 liters, 4 liters (21.4 mol) of 1-decene (product name "Linealene 10" manufactured by Idemitsu Kosan Co., Ltd.) was added in a nitrogen stream, and then, a solution obtained by dissolving biscyclopentadienyl zirconium dichloride (complex mass: 1,168 mg (4 mmol)) which is a metallocene catalyst, in toluene, and a solution obtained by dissolving methylalumoxane (40 mmol in terms of Al) which is a co-catalyst, in toluene were further added.

[0320] After the addition, the contents were stirred at 40°C for 20 hours to progress the oligomerization of the decene monomer, and then, 20 mL of methanol was added, to terminate the oligomerization reaction.

[0321] Subsequently, the reaction mixture was taken out from the three-necked flask, 4 liters of a 5 mol/L sodium hydroxide aqueous solution was added, and the contents were stirred at room temperature (25°C) for 4 hours to perform the liquid separating operation. Then, an organic layer of an upper layer was taken out to obtain a solution of a decene trimer.

(2) Hydrogenation Treatment

[0322] In an autoclave having an internal volume of 5 liters, 3 liters of the solution of the decene oligomer obtained in (1) above was added in a nitrogen stream, and then, a solution obtained by dissolving cobalt trisacetyl acetonate (catalyst mass: 3.0 g) in toluene and a solution obtained by dissolving triisobutylaluminum (30 mmol) in toluene were further added.

[0323] After the addition, the system was purged twice with hydrogen so that the temperature was raised, and the contents were held at a reaction temperature of 80°C under a hydrogen pressure of 0.9 MPa to progress the hydrogenation reaction. Then, the temperature was dropped to room temperature (25°C) for 4 hours after the start of the reaction, to terminate the hydrogenation reaction.

[0324] Subsequently, depressurization was performed, the reaction product in the autoclave was taken out, and a fraction having a distillation temperature of 240 to 270°C and a pressure of 530 Pa was separated by means of simple distillation, thereby obtaining an olefin-based polymer composed of a hydride of the decene trimer.

<Viscosity Index Improver (B)>

(Resin Component (B1)-1: Comb-Shaped Polymer)

[0325] Mass average molecular weight (Mw): 600,000, Mw/Mn: 2.9, SSI: 1, having at least a structural unit derived from a macromonomer with Mn of 500 or more (Resin Component (B1)-2: PMA)

[0326] Polymethacrylate (product name "Aclube 740" manufactured by Sanyo Kasei Co., Ltd.), mass average molecular weight (Mw): 230,000, Mw/Mn: 2.1.

<Imide-Based Dispersant (C)>

[0327] Polybutenyl succinic acid bisimide (non-boron-modified product): nitrogen content 1.2% by mass

<Other Lubricating Oil Additives>

(Metal-Based Detergent (D))

Calcium salicylate and magnesium salicylate

[0328] In Examples 1 to 4, Comparative Examples 1 to 4, and Comparative Example 6, calcium salicylate and magnesium salicylate were mixed, such that in the lubricating oil composition, the Ca content became 0.11% by mass, and the Mg content became 0.02% by mass.

[0329] In Comparative Example 5, calcium salicylate was mixed such that the Ca content in the lubricating oil composition became 0.23% by mass.

(Zinc Dithiophosphate (E))

Primary ZnDTP and secondary ZnDTP

[0330] In Examples 1 to 4, Comparative Examples 1 to 4, and Comparative Example 6, primary ZnDTP and secondary ZnDTP were mixed, such that in the lubricating oil composition, the P content became 0.07% by mass, and the Zn content became 0.08% by mass.

[0331] In Comparative Example 5, primary ZnDTP and secondary ZnDTP were mixed, such that in the lubricating oil composition, the P content became 0.08% by mass, and the Zn content became 0.09% by mass.

(Antioxidant)

[0332] In Examples 1-4 and Comparative Examples 1-6, an amine-based antioxidant was mixed. The added amount of the amine-based antioxidant in the lubricating oil composition was 0.5% by mass.

[Evaluation of Cleanliness at High Temperature]

[0333] The cleanliness at high temperature was evaluated for the lubricating oil compositions of Examples 1-4 and Comparative Examples 1-6.

[0334] First, the lubricating oil compositions of Examples 1 to 4 and Comparative Examples 1 to 6 were subjected to a deterioration treatment, in which the oil temperature of the lubricating oil compositions was set to 150 °C, and a NOx gas with a concentration: 4,000 vol. ppm was blown into the lubricating oil compositions for 72 hours. As a result of the deterioration treatment, the lubricating oil compositions were brought into the state after a running of about 16,000 km. The volume of a test container was 300 mL, and 100 mL of a lubricating oil composition was used.

[0335] A hot tube test was performed on the deteriorated lubricating oil compositions under a condition of a temperature of 260°C.

[0336] When a lubricating oil composition gains an evaluation score of 2.5 or higher among the scores of 0 to 10 of the hot tube test, it is evaluated that the high-temperature cleanliness of the lubricating oil composition is maintained for a long period of time.

[Evaluation of Oil Film Retainability]

[0337] The oil film thickness of each of the resulting lubricating oil compositions was measured under the following conditions. The oil film thickness was measured three times under the same conditions, and the average of the three measured values was taken as an EHL oil film thickness of the lubricating oil composition. When the EHL oil film thickness is 60 nm or more, it is evaluated that the oil film retainability of the corresponding lubricating oil composition is excellent.

- Apparatus Model: EHD2 (manufactured by PCS Instruments)
- Test specimen: steel ball (diameter: 7.5 mm)
- Disk: glass disc coated with SiO_2/Cr
- Oil temperature: 100°C
- Load: 20 N (surface pressure: 0.5 GPa)
- Speed: 100 mm/s
- Slide-roll ratio (SRR): 200%

[0338] Table 1 below represents the results.

Table 1

			Unit	Example 1	Example 2	Example 3	Example 4	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Composition of Lubricating Oil Composition	Base oil (A)	First olefin-Based polymer (A1-1)-1	mass%	55.89	81.40	-	-	65.90	-	-	-	82.39	-
		First olefin-Based polymer (A1-1)-2	mass%	-	-	81.34	81.52	-	-	-	86.00	-	82.00
		Second olefin-based polymer (A1-2)-1	mass%	-	-	-	-	15.00	-	-	-	-	-
		Second olefin-based polymer (A1-2)-2	mass%	-	-	-	-	-	-	-	-	5.50	-
		Mineral oil (A2)-1	mass%	-	-	-	-	-	-	41.00	-	-	-
		Mineral oil (A2)-2	mass%	25.45	-	-	-	-	-	41.00	-	-	-
		Ester-based oil (A3-1)	mass%	-	-	-	-	-	82.00	-	-	-	-
	Viscosity index improver (B)	Resin component (B1)-1	mass%	0.66	0.60	0.66	-	1.10	-	-	2.00	0.11	-
		Resin component (B1)-2	mass%	-	-	-	0.48	-	-	-	-	-	-
	Imide-based dispersant (C)		mass%	10.00	10.00	10.00	10.00	10.00	10.00	10.00	4.00	4.00	10.00

(continued)

		Unit	Example 1	Example 2	Example 3	Example 4	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
	Other lubricating oil additives	mass%	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Total	mass%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Content of nitrogen atoms derived from imide-based dispersant (C)	mass%	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.05	0.05	0.12
	(B1)/(A1-1)	-	0.012	0.007	0.008	0.006	0.017	-	-	0.023	0.001	0.000
Composition of Base Oil (A)	Content of first olefin-based polymer (A1-1)	mass%	68.7	100.0	100.0	100.0	81.5	-	-	100.0	93.7	100.0
	Content of second olefin-based polymer (A1-2)	mass%	-	-	-	-	18.5	-	-	-	6.3	-
	Content of mineral oil (A2)	mass%	31.3	-	-	-	-	-	100.0	-	-	-
	Content of ester-based oil (A3-1)	mass%	-	-	-	-	-	100.0	-	-	-	-
Physical properties of lubricating oil composition	40°C kinematic viscosity	mm^2/s	22.9	25.7	25.2	26.5	22.5	20.1	26.3	19.8	18.8	22.8
	100°C kinematic viscosity	mm^2/s	5.5	5.8	5.9	6.0	5.7	4.9	5.4	5.5	4.5	5.0
	Viscosity index	-	193	180	193	182	211	184	147	247	165	154
	HTHS viscosity at 150°C	mPa s	2.0	2.1	2.1	2.1	2.1	2.1	2.0	2.0	1.7	1.8
	NOACK evaporation loss	mass%	19	10	19	19	23	10	23	19	14.5	19
	Aniline point	°C	110 or higher	110 or higher	110 or higher	110 or higher	110 or higher	room temperature	110 or higher	110 or higher	110 or higher	110 or higher

(continued)

		Unit	Example 1	Example 2	Example 3	Example 4	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Evaluation results	Cleanliness at high temperature (hot tube test: 260°C)	-	2.5	2.5	2.5	2.5	2.5	2.5	2.5	0	0	2.5
	Oil film retainability (oil film thickness at 100°C)	nm	60	65	64	66	61	63	65	54	49	58

[0339] Table 1 confirms the following:
It is confirmed that the lubricating oil compositions of Examples 1 to 4 exhibit the low evaporativity, the excellent oil film retainability, and the excellent cleanliness at high temperature. Further, it is confirmed that the aniline point is 95°C or higher, which indicates the excellent compatibility with the rubber material.

[0340] Meanwhile, it is confirmed that the lubricating oil composition of Comparative Example 1 is inferior in low evaporativity, since the content of the second olefin polymer (A1-2) is 18.5% by mass or more based on the total amount of the base oil (A).

[0341] It is confirmed that the lubricating oil composition of Comparative Example 2 is inferior in compatibility with the rubber material, since the aniline point thereof is the room temperature.

[0342] It is confirmed that the lubricating oil composition of Comparative Example 3 is inferior in low evaporatitivty, since the lubricating oil composition does not contain the first olefin-based polymer (A1-1).

[0343] It is confirmed that the lubricating oil compositions of Comparative Examples 4 and 5 are inferior in cleanliness at high temperature, since the content of nitrogen atoms derived from the imide-based dispersant (C) is less than 0.06% by mass. Further, it is confirmed that the lubricating oil compositions of Comparative Examples 4 and 5 are also inferior in oil film retainability. Further, it is confirmed that oil film retainability of the lubricating oil composition of Comparative Example 5 is more inferior than that of Comparative Example 4, since the content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is 0.001 or less in terms of a mass ratio.

[0344] It is confirmed that the lubricating oil composition of Comparative Example 6 is inferior in oil film retainability, since the lubricating oil composition does not contain the viscosity index improver (B), and the content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is 0.001 or less in terms of a mass ratio.

Claims

1. A lubricating oil composition comprising a base oil (A) containing an olefin-based polymer (A1), a viscosity index improver (B), and an imide-based dispersant (C),

   wherein a first olefin-based polymer (A1-1) having a kinematic viscosity at 100°C of 3.0 mm^2/s or more is contained as the olefin-based polymer (A1), and a content of the first olefin-based polymer (A1-1) is 30% by mass or more based on a total amount of the base oil (A),
   a second olefin-based polymer (A1-2) having a kinematic viscosity at 100°C of less than 3.0 mm^2/s is not contained as the olefin-based polymer (A1), or is contained in a content of less than 18.5% by mass based on the total amount of the base oil (A),
   a content of a resin component (B1) derived from the viscosity index improver (B) is 0.01% by mass or more based on a total amount of the lubricating oil composition,
   a content of nitrogen atoms derived from the imide-based dispersant (C) is 0.06% by mass or more based on the total amount of the lubricating oil composition,
   a content ratio of the resin component (B1) derived from the viscosity index improver (B) and the first olefin-based polymer (A1-1) [(B1)/(A1-1)] is more than 0.001 in terms of a mass ratio,
   the kinematic viscosity at 100°C is 5.0 mm^2/s or more and less than 7.1 mm^2/s, and
   an aniline point is 95°C or higher.

2. The lubricating oil composition according to claim 1, wherein the base oil (A) contains one or more selected from the group consisting of a mineral oil (A2), and a synthetic oil (A3) other than the first olefin-based polymer (A1-1) and the second olefin-based polymer (A1-2).

3. The lubricating oil composition according to claim 2, wherein a content of the mineral oil (A2) is 50% by mass or less based on the total amount of the base oil (A).

4. The lubricating oil composition according to any one of claims 1 to 3, wherein a high-temperature high-shear (HTHS) viscosity at 150°C is 2.0 mPa·s or more and less than 2.3 mPa·s.

5. The lubricating oil composition according to any one of claims 1 to 4, wherein a mass average molecular weight (Mw) of the resin component (B1) is 200,000 or more.

6. The lubricating oil composition according to any one of claims 1 to 5, further comprising a metal-based detergent (D).

7. The lubricating oil composition according to any one of claims 1 to 6, further comprising zinc dithiophosphate (E).

8. The lubricating oil composition according to any one of claims 1 to 7, which is used in an internal combustion engine.

9. The lubricating oil composition according to any one of claims 1 to 7, which is used in an internal combustion engine equipped with a forced-induction device.

10. A method for lubricating an internal combustion engine using the lubricating oil composition according to any one of claims 1 to 7.

11. The method according to claim 10, wherein the internal combustion engine is an internal combustion engine equipped with a forced-induction device.

INTERNATIONAL SEARCH REPORT	International application No. PCT/JP2021/009859

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. C10M169/04(2006.01)i, C10N20/02(2006.01)n, C10N20/04(2006.01)n, C10N30/00(2006.01)n, C10N30/04(2006.01)n, C10N30/06(2006.01)n, C10N40/25(2006.01)n, C10M101/02(2006.01)n, C10M107/02(2006.01)n, C10M133/56(2006.01)n, C10M137/10(2006.01)n

FI: C10M169/04, C10M107/02, C10M133/56, C10M101/02, C10M137/10A, C10N40:25, C10N20:04, C10N20:02, C10N30:04, C10N30:06, C10N30:00Z

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. C10M169/04, C10N20/02, C10N20/04, C10N30/00, C10N30/04, C10N30/06, C10N40/25, C10M101/02, C10M107/02, C10M133/56, C10M137/10

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2014-210844 A (COSMO OIL LUBRICANTS CO., LTD.) 13 November 2014 (2014-11-13), claims, paragraphs [0002]-[0008], [0016], [0017], [0019], [0034], example 1	1-11
Y	WO 2014/136973 A1 (IDEMITSU KOSAN CO., LTD.) 12 September 2014 (2014-09-12), claims, paragraphs [0004], [0009], [0042], examples	1-11
Y	JP 2010-100707 A (IDEMITSU KOSAN CO., LTD.) 06 May 2010 (2010-05-06), claims, paragraphs [0005], [0013], [0040], examples	1-11

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

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"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	"&" document member of the same patent family

Date of the actual completion of the international search 07 May 2021	Date of mailing of the international search report 18 May 2021
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/009859

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2019/031404 A1 (IDEMITSU KOSAN CO., LTD.) 14 February 2019 (2019-02-14), claims, paragraphs [0071], [0158], examples	1-11
Y	浜口 仁, 世界の潤滑油/潤滑油添加剤技術と市場・規格動向, augmented revised edition, first edition, S&T 出版株式会社, 07 October 2016, pp. 165-168, non-official translation (HAMAGUCHI, Hitoshi, Global lubricants / lubricants additives technology and market / standard trends, S & T PUBLISHING CO., LTD.)	1-11
A	US 5972852 A (EXXON CHEMICAL PATENTS, INC.) 26 October 1999 (1999-10-26)	1-11

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/009859

JP 2014-210844 A	13 November 2014	(Family: none)
WO 2014/136973 A1	12 September 2014	US 2016/0024416 A1 claims, paragraphs [0008], [0016]-[0020], [0071], examples EP 2966153 A1 CN 105189718 A
JP 2010-100707 A	06 May 2010	(Family: none)
WO 2019/031404 A1	14 February 2019	EP 3666862 A1 claims, paragraphs [0132], [0274], examples CN 110892052 A
US 5972852 A	26 October 1999	EP 776355 A1

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