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

(11) EP 3 766 949 A1

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

(43) Date of publication:
20.01.2021 Bulletin 2021/03

(21) Application number: **19768240.4**

(22) Date of filing: **12.03.2019**

(51) Int Cl.:
C10M 169/04 *(2006.01)*
C10M 101/02 *(2006.01)*
C10M 143/12 *(2006.01)*
C10N 20/00 *(2006.01)*
C10N 20/04 *(2006.01)*
C10N 30/00 *(2006.01)*
C10N 30/08 *(2006.01)*
C10N 40/25 *(2006.01)*

(86) International application number:
PCT/JP2019/010032

(87) International publication number:
WO 2019/176944 (19.09.2019 Gazette 2019/38)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **12.03.2018 JP 2018044412**

(71) Applicant: **Idemitsu Kosan Co.,Ltd.**
Chiyoda-ku
Tokyo 100-8321 (JP)

(72) Inventor: **KUSUMOTO, Tatsuya**
Ichihara-shi, Chiba 299-0107 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) LUBRICATING OIL COMPOSITION

(57) The present invention relates to a lubricating oil composition containing a base oil (A) and a viscosity index improver (B) such that in X-ray small-angle scattering spectra obtained through measurement at 40°C and 100°C, a ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ between $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ each of which is an absolute value of a slope of a straight line calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method, is 1.5 or more.

Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

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

Background Art

[0002] In recent years, for the purposes of effective active use of oil resources and emission reduction of carbon dioxide, fuel consumption reduction of vehicles, such as automobiles, is eagerly required. For that reason, a demand of fuel consumption reduction for a lubricating oil composition to be used for engines of vehicles, such as automobiles, is also becoming strong.

[0003] For example, PTL 1 discloses a lubricating oil composition for internal combustion engine, in which an ashless dispersant, a viscosity index improver having a permanent shear stability index (PSSI) of 10 to 100, and at least one selected from a metal-based detergent, an antioxidant, an anti-wear agent, and a friction modifier are contained in a lubricant base oil, and a ratio of a viscosity index and a high temperature high shear viscosity (HTHS viscosity) at 100°C of the composition is regulated to 32 or more.

[0004] According to PTL 1, it is mentioned that the foregoing lubricating oil composition is excellent in fuel consumption reducing properties, sludge suppression, and engine detergency.

Citation List

Patent Literature

[0005] PTL 1: JP 2007-217494 A

Summary of Invention

Technical Problem

[0006] For example, an engine to be mounted in a general vehicle, such as an automobile, becomes very high in temperature at the time of high-speed operation, and an engine oil also rises close to 100°C, whereas the temperature of the engine oil in a practical use region of the engine is about 80°C.

[0007] In addition, an engine oil which is used for a hybrid car is heated and becomes high in temperature at the time of engine start; but at the time of motor operation, the engine becomes low in speed, and the engine oil becomes low in temperature as about 40 to 50°C.

[0008] In other words, the engine oil occasionally becomes low in temperature as about 40°C, whereas it occasionally becomes high in temperature as about 100°C, according to the kind or operation condition of the engine. An engine oil having excellent fuel consumption reduction performance even in such a wide temperature region is demanded.

[0009] PTL 1 does not study the fuel consumption reduction performance relative to a lubricating oil composition for internal combustion engine described in the foregoing patent literature from such a viewpoint, and the foregoing lubricating oil composition for internal combustion engine leaves room for further improvement from the viewpoint of improvement of the fuel consumption reducing properties.

[0010] In view of the aforementioned problem, the present invention has been made, and an object thereof is to provide a lubricating oil composition capable of stably revealing excellent fuel consumption reducing properties even in use in a wide temperature environment of from a low-temperature region to a high-temperature region.

Solution to Problem

[0011] The present inventor and others have found that a lubricating oil composition containing a viscosity index improver satisfying a specified parameter expressing a large structural change due to temperature in oil together with a base oil is able to solve the aforementioned problem.

[0012] Specifically, the present invention provides the following [1].

[1] A lubricating oil composition containing a base oil (A) and a viscosity index improver (B) in which a ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ between $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ as calculated through the following operations (i) to (iii) is 1.5 or more:

· Operation (i): a sample oil having the viscosity index improver (B) dissolved in a mineral oil is prepared, and the X-ray small-angle scattering measurement is performed under a temperature condition at 40°C and 100°C, respectively, to acquire X-ray small-angle scattering spectra (x axis: scattering vector q (nm^{-1}), y axis: common logarithm log (I) of scattering intensity I);
· Operation (ii): in the X-ray small-angle scattering spectrum at 40°C as obtained in the operation (i), an absolute value $\Delta|\alpha(40)|$ of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method; and
· Operation (iii): in the X-ray small-angle scattering spectrum at 100°C as obtained in the operation (i), an absolute value $\Delta|\alpha(100)|$of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method.

Advantageous Effects of Invention

[0013] The lubricating oil composition of the present invention is able to stably reveal excellent fuel consumption reducing properties even in use in a wide temperature environment of from a low-temperature region to a high-temperature region.

Description of Embodiments

[0014] In this specification, the kinematic viscosity and the viscosity index each mean a value measured in conformity with JIS K2283:2000.

[0015] In this specification, the weight average molecular weight (Mw) and the number average molecular weight (Mn) of each of the components are each a value expressed in terms of standard polystyrene as measured by the gel permeation chromatography (GPC), and specifically, a value measured according to the method described in the section of Examples.

[0016] In this specification, for example, the "alkyl (meth)acrylate" is used as a terminology expressing both an "alkyl acrylate" and a "alkyl methacrylate", and other analogous terms or similar expressions are also the same.

[Lubricating Oil Composition]

[0017] The lubricating oil composition of the present invention contains a base oil (A) and a viscosity index improver (B) in which a ratio [$\Delta|\alpha(40)|/\Delta|\alpha(100)|$] between $\Delta|\alpha(40)|$and $\Delta|\alpha(100)|$ as calculated through the following operations (i) to (iii) is 1.5 or more:

- Operation (i): a sample oil having the viscosity index improver (B) dissolved in a mineral oil is prepared, and the X-ray small-angle scattering measurement is performed under a temperature condition at 40°C and 100°C, respectively, to acquire X-ray small-angle scattering spectra (x axis: scattering vector q (nm^{-1}), y axis: common logarithm log (I(q)) of scattering intensity I(q));
- Operation (ii): in the X-ray small-angle scattering spectrum at 40°C as obtained in the operation (i), an absolute value $\Delta|\alpha(40)|$ of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method; and
- Operation (iii): in the X-ray small-angle scattering spectrum at 100°C as obtained in the operation (i), an absolute value $\Delta|\alpha(100)|$ of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method.

[0018] Specific methods of the aforementioned operations (i) to (iii) are those as described in the section of Examples.

[0019] The base oil (A) that is contained in the lubricating oil composition of the present invention and the mineral oil that is used for preparation of the sample oil in the operation (i) may be the same as or different from each other.

[0020] In other words, it should not be construed that the base oil (A) that is contained in the lubricating oil composition of the present invention is limited to the mineral oil that is used for preparation of the sample oil in the operation (i).

[0021] The values of $\Delta|\alpha(40)|$and $\Delta|\alpha(100)|$ calculated through the operations (i) to (iii) are those expressing the shapes of the viscosity index improver (B) dispersed in the sample oil at 40°C and 100°C, respectively in terms of a numerical value.

[0022] As the values of $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ are small, a polymer chain constituting the viscosity index improver (B) is dispersed and dissolved in the base oil, whereby the viscosity index improver (B) becomes an extended shape in a thin rod form or a thin disc form.

[0023] In the case where the viscosity index improver (B) becomes an extended shape in a thin rod form or a thin disc form, the viscosity index improver (B) becomes a state of being widely dispersed in the sample oil, and therefore, it may be considered that the viscosity of the sample oil increases.

[0024] Meanwhile, as the values of $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ are large, the viscosity index improver (B) becomes a spherical aggregate shape at nanometer levels.

[0025] In the case where the viscosity index improver (B) becomes a spherical aggregate shape, dispersion of the viscosity index improver (B) in the sample oil is suppressed, and therefore, it may be considered that the viscosity of the sample oil decreases.

[0026] The viscosity index improver is blended for the purpose of giving an effect for increasing the viscosity of the lubricating oil composition.

[0027] The viscosity index improver is required to sufficiently exhibit the effect for increasing the viscosity in a high-temperature region where the viscosity of the base oil decreases, whereas in a low-temperature region where the viscosity of the base oil increases, the viscosity index improver is desired to have such properties that the increase of the viscosity is suppressed to some extent such that the viscosity of the lubricating oil composition does not excessively increase.

[0028] In other words, the viscosity index improver is desired to become a state of being widely dispersed in the base oil in a high-temperature region, and therefore, it is preferred that the value of $\Delta|\alpha(100)|$ resulting from digitalization of the shape of the viscosity index improver (B) at 100°C that is the high-temperature region is small as far as possible.

[0029] Meanwhile, in a low-temperature region, the viscosity index improver is desired to have such properties that the increase of the viscosity is suppressed to some extent such that the viscosity of the lubricating oil composition does not excessively increase, and therefore, it is preferred that the value of $\Delta|\alpha(40)|$ resulting from digitalization of the shape of the viscosity index improver (B) at 40°C that is the low-temperature region is large as far as possible.

[0030] It may also be said that the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ between $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ is a parameter expressing a degree of difference in shape at between 40°C and 100°C with respect to the shape of the viscosity index improver (B) dispersed in the sample oil.

[0031] In other words, the viscosity index improver whose ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ is large may be said to be one having high temperature dependence and may be said to be one in which by changing the shape at every temperature, the viscosity of the lubricating oil composition can be held within an appropriate range.

[0032] It is preferred that the lubricating oil composition according to one embodiment of the present invention further contains an organic molybdenum-based compound (C).

[0033] In addition, the lubricating oil composition according to one embodiment of the present invention may further contain an additive for lubricating oil other than the viscosity index improver (B) within a range where the effects of the present invention are not impaired.

[0034] In the lubricating oil composition according to one embodiment of the present invention, a total content of the components (A) and (B) is preferably 60 to 100% by mass, more preferably 70 to 100% by mass, still more preferably 80 to 100% by mass, and yet still more preferably 85 to 100% by mass on the basis of the whole amount (100% by mass) of the lubricating oil composition.

[0035] Details of each of the components to be contained in the lubricating oil composition according to one embodiment of the present invention are hereunder described.

<Base Oil (A)>

[0036] The base oil (A) that is contained in the lubricating oil composition according to one embodiment of the present invention may be a mineral oil or may be a synthetic oil, and a mixed oil of a mineral oil and a synthetic oil may also be used.

[0037] Examples of the mineral oil include atmospheric residues obtained by subjecting a crude oil, such as a paraffinic crude oil, an intermediate base crude oil, and a naphthenic crude oil, to atmospheric distillation; distillates obtained by subjecting such an atmospheric residue to distillation under reduced pressure; mineral oils obtained by subjecting the distillate to one or more refining treatments, such as solvent deasphalting, solvent extraction, hydro-cracking, solvent dewaxing, catalytic dewaxing, and hydrorefining; and mineral oils (GTL) obtained by isomerizing a wax (GTL wax (Gas to Liquids Wax)) produced by a Fischer-Tropsch process or the like from a natural gas.

[0038] These mineral oils may be used alone or may be used in combination of two or more thereof.

[0039] Examples of the synthetic oil include poly-α-olefins, such as an α-olefin homopolymer or an α-olefin copolymer (for example, an α-olefin copolymer having 8 to 14 carbon atoms, such as an ethylene-α-olefin copolymer); isoparaffins; various esters, such as a dibasic acid ester (for example, ditridecyl glutarate), a polyol ester, a dibasic acid ester, an aromatic ester (for example, 2-ethylhexyl trimellitate and 2-ethylhexyl pyromellitate), and a phosphate ester; various ethers, such as a polyalkylene glycol and a polyphenyl ether; alkylbenzenes; and alkylnaphthalenes.

[0040] These synthetic oils may be used alone or may be used in combination of two or more thereof.

[0041] From the viewpoint of improving dispersibility of the viscosity index improver (B), it is preferred that the base oil (A) that is used in one embodiment of the present invention contains a mineral oil.

[0042] As the mineral oil, a mineral oil classified into Group 2 or Group 3 of the base stock categories of the API

(American Petroleum Institute) is preferred; and a mineral oil classified into the foregoing Group 3 is more preferred.

[0043] In the base oil (A) that is used in one embodiment of the present invention, the content of the mineral oil is preferably 50 to 100% by mass, more preferably 65 to 100% by mass, still more preferably 80 to 100% by mass, and yet still more preferably 90 to 100% by mass on the basis of the whole amount (100% by mass) of the base oil (A).

[0044] A kinematic viscosity at 40°C of the base oil (A) that is used in one embodiment of the present invention is preferably 5 to 80 mm^2/s, more preferably 10 to 60 mm^2/s, still more preferably 12 to 40 mm^2/s, and yet still more preferably 14 to 30 mm^2/s.

[0045] A kinematic viscosity at 100°C of the base oil (A) that is used in one embodiment of the present invention is preferably 1.0 to 7.0 mm^2/s, more preferably 2.0 to 6.0 mm^2/s, still more preferably 3.0 to 5.0 mm^2/s, and yet still more preferably 3.5 to 4.5 mm^2/s.

[0046] From the viewpoint of not only suppressing the change in viscosity to be caused due to a change in temperature but also improving the fuel consumption reducing properties, a viscosity index of the base oil (A) that is used in one embodiment of the present invention is preferably 80 or more, more preferably 100 or more, still more preferably 110 or more, and yet still more preferably 120 or more.

[0047] In the lubricating oil composition according to one embodiment of the present invention, in the case of using a mixed oil resulting from combining two or more base oils, it is preferred that the kinematic viscosity and the viscosity index of the mixed oil fall within the aforementioned ranges, respectively.

[0048] In the lubricating oil composition according to one embodiment of the present invention, the content of the base oil (A) is preferably 55% by mass or more, more preferably 60% by mass or more, still more preferably 65% by mass or more, and yet still more preferably 70% by mass or more, and it is preferably 99.5% by mass or less, more preferably 99% by mass or less, and still more preferably 95% by mass or less, on the basis of the whole amount (100% by mass) of the lubricating oil composition.

<Viscosity Index Improver (B)>

[0049] The lubricating oil composition of the present invention contains the viscosity index improver (B) in which the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ between $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ as calculated through the aforementioned operations (i) to (iii) is 1.5 or more.

[0050] In the case where the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ of the viscosity index improver (B) is less than 1.5, the degree in change of the shape at every temperature is small, and it is difficult to regulate an appropriate viscosity corresponding to the temperature of the lubricating oil composition, resulting in causing a lowering of the fuel consumption reducing properties.

[0051] Meanwhile, by providing the lubricating oil composition containing the viscosity index improver (B) in which the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ is 1.5 or more, it is possible to hold the viscosity within an appropriate range even in use in a wide temperature environment of from a low-temperature region to a high-temperature region, and therefore, excellent fuel consumption reducing properties can be stably revealed.

[0052] From the aforementioned viewpoint, in the lubricating oil composition according to one embodiment of the present invention, the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ of the viscosity index improver (B) is preferably 1.55 or more, more preferably 1.58 or more, still more preferably 1.6 or more, yet still more preferably 1.65 or more, even yet still more preferably 1.7 or more, and much more preferably 1.8 or more.

[0053] The value of $\Delta|\alpha(40)|$ of the viscosity index improver (B) that is used in one embodiment of the present invention is preferably 2.3 $(1/(nm^{-1}))$ or more, more preferably 2.5 $(1/(nm^{-1}))$ or more, still more preferably 2.8 $(1/(nm^{-1}))$ or more, and yet still more preferably 3.2 $(1/(nm^{-1}))$ or more, and it is preferably 6.0 $(1/(nm^{-1}))$ or less, from the viewpoint of providing a viscosity index improver capable of suppressing the increase of the viscosity of the lubricating oil composition to some extent such that the foregoing viscosity does not excessively increase in a low-temperature region.

[0054] The value of $\Delta|\alpha(100)|$ of the viscosity index improver (B) that is used in one embodiment of the present invention is preferably 3.5 $(1/(nm^{-1}))$ or less, more preferably 3.2 $(1/(nm^{-1}))$ or less, still more preferably 3.0 $(1/(nm^{-1}))$ or less, and yet still more preferably 2.7 $(1/(nm^{-1}))$ or less, and it is preferably 1.2 $(1/(nm^{-1}))$ or more, from the viewpoint of providing a viscosity index improver which becomes a state of being widely dispersed in the base oil in a high-temperature region, thereby enabling the effect for increasing the viscosity to be sufficiently exhibited.

[0055] In one embodiment of the present invention, the viscosity index improver (B) may be one constituted of a single polymer or may be one constituted of two or more polymers. In the case where the viscosity index improver (B) is one constituted of two or more polymers, the aforementioned ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$, the aforementioned value of $\Delta|\alpha(40)|$, and the aforementioned value of $\Delta|\alpha(100)|$ of each of the polymers have only to fall within the aforementioned ranges, respectively. Among two or more polymers, even when a part thereof falls outside the aforementioned ranges regarding the aforementioned ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$, the aforementioned value of $\Delta|\alpha(40)|$, and the aforementioned value of $\Delta|\alpha(100)|$, the whole of the viscosity index improver (B) containing other polymer or polymers have only to fall within the aforementioned ranges, respectively.

[0056] In the lubricating oil composition according to one embodiment of the present invention, from the viewpoint of providing a lubricating oil composition capable of stably revealing excellent fuel consumption reducing properties even in use in a wide temperature environment of from a low-temperature region to a high-temperature region, the content of the viscosity index improver (B) expressed in terms of a resin component is preferably 0.5 to 8.0% by mass, more preferably 0.7 to 5.0% by mass, still more preferably 1.0 to 4.0% by mass, and yet still more preferably 1.0 to 3.5% by mass on the basis of the whole amount (100% by mass) of the lubricating oil composition.

[0057] Taking into consideration handling properties and solubility in the base oil (A), in many cases, the viscosity index improver (B) is put on the market in a form of a solution in which the resin component constituting the viscosity index improver is dissolved in a diluent oil, such as a mineral oil and a synthetic oil.

[0058] In this specification, the aforementioned "content of the viscosity index improver (B) expressed in terms of a resin component" is the content expressed in terms of the resin component constituting the viscosity index improver, from which the mass of the diluent oil is excluded.

[0059] The aforementioned "resin component" means a polymer having a weight average molecular weight (Mw) of 1,000 or more and having a fixed repeating unit.

[0060] In the lubricating oil composition according to one embodiment of the present invention, from the viewpoint of providing a lubricating oil composition capable of stably revealing excellent fuel consumption reducing properties even in use in a wide temperature environment of from a low-temperature region to a high-temperature region, the weight average molecular weight (Mw) of the viscosity index improver (B) is preferably 100,000 to 900,000, more preferably 200,000 to 800,000, still more preferably 300,000 to 750,000, and yet still more preferably 350,000 to 700,000.

[0061] From the same viewpoint as that mentioned above, a molecular weight distribution (Mw/Mn) of the viscosity index improver (B) (wherein Mw represents a weight average molecular weight of the viscosity index improver (B), and Mn represents a number average molecular weight of the viscosity index improver (B)) is preferably 6.00 or less, more preferably 3.00 or less, still more preferably 2.00 or less, yet still more preferably 1.95 or less, and even yet still more preferably 1.90 or less.

[0062] As the molecular weight distribution of the viscosity index improver (B) becomes small, the fuel consumption reduction performance of the lubricating oil composition containing the viscosity index improver (B) together with the base oil (A) tends to be more improved.

[0063] Although the molecular weight distribution (Mw/Mn) of the viscosity index improver (B) is not particularly limited with respect to a lower limit value thereof, it is typically 1.05 or more, preferably 1.10 or more, and more preferably 1.15 or more.

[0064] Now, it is possible to regulate the aforementioned ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$, the aforementioned value of $\Delta|\alpha(40)|$, and the aforementioned value of $\Delta|\alpha(100)|$ of the viscosity index improver (B) by the kind and content of the structural unit of the polymer constituting the viscosity index improver (B) as well as the structure of the polymer.

[0065] For example, it is preferred that the viscosity index improver (B) contains a polymer (B1) having a structural unit (β1) derived from a monomer selected from butadiene and hydrogenated butadiene.

[0066] In the viscosity index improver (B) containing the polymer (B1), while the value of $\Delta|\alpha(40)|$ becomes large, the value of $\Delta|\alpha(100)|$ becomes likely small, and thus, the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ is readily regulated to a large value.

[0067] From the aforementioned viewpoint, in the polymer (B1) that is used in one embodiment of the present invention, the content of the structural unit (β1) is preferably 0.1 to 70 mol%, more preferably 0.3 to 60 mol%, and still more preferably 0.5 to 50 mol% relative to the whole amount (100 mol%) of the structural units of the polymer (B1).

[0068] It is more preferred that the polymer (B1) contains a structural unit (β2) derived from a hydroxy group-containing vinyl monomer together with the structural unit (β1).

[0069] In the polymer (B1) that is used in one embodiment of the present invention, the content of the structural unit (β2) is preferably 0.1 to 30 mol%, more preferably 0.5 to 20 mol%, still more preferably 1.0 to 15 mol%, and yet still more preferably 1.5 to 10 mol% relative to the whole amount (100 mol%) of the structural units of the polymer (B1).

[0070] The hydroxy group-containing vinyl monomer is mentioned later.

[0071] The content of the polymer (B1) in the viscosity index improver (B) that is used in one embodiment of the present invention is preferably 70 to 100% by mass, more preferably 80 to 100% by mass, still more preferably 90 to 100% by mass, and yet still more preferably 95 to 100% by mass on the basis of the whole amount (100% by mass) of the viscosity index improver (B).

[0072] From the viewpoint of regulating the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ to the aforementioned range, the polymer (B1) that is used as the viscosity index improver (B) in one embodiment of the present invention is preferably at least one selected from a styrene-isoprene-butadiene copolymer (B11) and a comb-shaped polymer (B12).

[0073] With respect to the components (B11) and (B12), preferred embodiments are hereunder described from the viewpoint of regulating the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ to the aforementioned range.

<Styrene-Isoprene-Butadiene Copolymer (B11)>

[0074] The styrene-isoprene-butadiene copolymer (B11) that is used in one embodiment of the present invention may be a copolymer having structural units derived from styrene, isoprene, and butadiene, respectively.

[0075] In the styrene-isoprene-butadiene copolymer (B11), the structural unit derived from butadiene may be one in which a part or the whole thereof is substituted with a structural unit derived from hydrogenated butadiene.

[0076] A mode of the copolymer of the component (B11) may be a block copolymer or may be a random copolymer.

[0077] Suitable ranges of the weight average molecular weight (Mw) and the molecular weight distribution (Mw/Mn) of the component (B11) are the same as the suitable ranges prescribed above for the component (B).

[0078] In the component (B11), the content of the structural unit (β1) derived from the monomer selected from butadiene and hydrogenated butadiene is preferably 2.5 to 30 mol%, more preferably 3.0 to 25 mol%, still more preferably 3.5 to 20 mol%, and yet still more preferably 4.0 to 15 mol% relative to the whole amount (100 mol%) of the structural units of the component (B11).

[0079] In the component (B11), the content of a structural unit (p1) derived from styrene is preferably 1 to 50 mol%, more preferably 3 to 40 mol%, still more preferably 5 to 30 mol%, and yet still more preferably 7 to 25 mol% relative to the whole amount (100 mol%) of the structural units of the component (B11).

[0080] In the component (B11), the content of a structural unit (p2) derived from isoprene is preferably 10 to 95 mol%, more preferably 25 to 90 mol%, still more preferably 40 to 85 mol%, and yet still more preferably 55 to 80 mol% relative to the whole amount (100 mol%) of the structural units of the component (B11).

[0081] The component (B11) may have a structural unit derived from a monomer other than styrene, isoprene, and butadiene (inclusive of hydrogenated butadiene, too).

[0082] However, in the component (B11), a total content of the structural units (β1), (p1), and (p2) is preferably 80 to 100 mol%, more preferably 85 to 100 mol%, still more preferably 90 to 100 mol%, and yet still more preferably 95 to 100 mol% relative to the whole amount (100 mol%) of the structural units of the component (B11).

<Comb-Shaped Polymer (B12)>

[0083] In this specification, the "comb-shaped polymer" refers to 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.

[0084] The comb-shaped polymer (B12) that is used in the present invention is a polymer having a structural unit (X1) derived from a macromonomer (x1), and the macromonomer (x1) is preferably a high-molecular weight monomer having the structural unit (β1) derived from a monomer selected from butadiene and hydrogenated butadiene.

[0085] In other words, the macromonomer (x1) which the comb-shaped polymer (B12) has is corresponding to the aforementioned "high-molecular weight side chain".

[0086] In the present invention, the aforementioned "macromonomer" means a high-molecular weight monomer having a polymerizable functional group and is preferably a high-molecular weight monomer having a polymerizable functional group in an end thereof.

[0087] As the side chain of the comb-shaped polymer is long, the comb-shaped polymer is more likely dispersed in a wide range in the high-temperature region, whereas it is more likely aggregated in the low-temperature region, and thus, the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ becomes large more likely.

[0088] In other words, as the molecular weight of the macromonomer (x1) of the comb-shaped polymer (B12) is large, the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ is more likely regulated to a large value.

[0089] In particular, when the macromonomer (x1) which the comb-shaped polymer (B12) has is the high-molecular weight monomer having the structural unit (β1) derived from the monomer selected from butadiene and hydrogenated butadiene, the ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ is likely regulated to a larger value.

[0090] From the aforementioned viewpoint, a 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, even yet still more preferably 3,000 or more, and much more preferably 4,000 or more, and it 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.

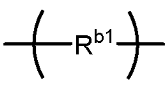
[0091] From the aforementioned viewpoint, in the comb-shaped polymer (B12) that is used in one embodiment of the present invention, the content of the structural unit (X1) is preferably 0.1 to 20 mol%, more preferably 0.3 to 10 mol%, and still more preferably 0.5 to 5 mol% on the basis of the whole amount (100 mol%) of the structural units of the comb-shaped polymer (B12).

[0092] Examples of the polymerizable functional group which the macromonomer (x1) has 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 $CH_2=CCH_3-CONH-$.

[0093] The content of the structural unit (β1) derived from the monomer selected from butadiene and hydrogenated butadiene in the macromonomer (x1) is preferably 0.5 to 100 mol%, more preferably 1 to 100 mol%, still more preferably 1 to 50 mol%, yet still more preferably 1 to 20 mol%, and even yet still more preferably 1 to 5 mol% on the basis of the whole amount (100 mol%) of the structural units of the macromonomer (x1).

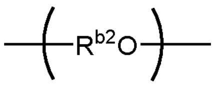
[0094] The macromonomer (x1) may also have, for example, at least one selected from repeating units represented by the following general formulae (i) to (iii) in addition to the structural unit (β1).

[0095] In the case where the macromonomer (x1) is a copolymer, a mode of the copolymerization may be a block copolymer or may be a random copolymer.



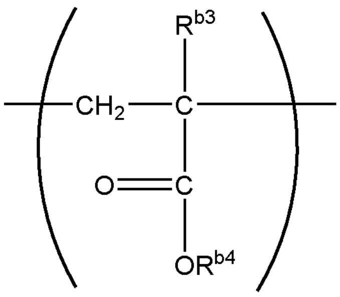
$$-\!\left(R^{b1}\right)\!-$$

(i)



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

(ii)



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

(iii)

[0096] In the general formula (i), 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 pentylene group, a hexylene group, a heptylene group, an octylene group, a nonylene group, a decylene group, and a 2-ethylhexylene group.

[0097] In the general formula (ii), 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.

[0098] In the general formula (iii), R^{b3} represents a hydrogen atom or a methyl group.

[0099] 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, a n-propyl group, a n-butyl group, a n-pentyl group, a n-hexyl group, a n-heptyl group, a n-octyl group, a n-nonyl group, a 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.

[0100] In the case where the macromonomer (x1) has a plurality of repeating units represented by each of the general formulae (i) to (iii), R^{b1}'s, R^{b2}'s, R^{b3}'s, and R^{b4}'s may be each the same as or different from each other.

[0101] The comb-shaped polymer (B12) that is used in one embodiment of the present invention may be a homopolymer composed of only the structural unit (X1) derived from one kind of the macromonomer (x1) or may be a copolymer containing the structural unit (X1) derived from two or more kinds of the macromonomer (x1).

[0102] In addition, the comb-shaped polymer (B12) that is used in one embodiment of the present invention may also be a copolymer containing the structural unit derived from the macromonomer (x1) as well as a structural unit (X2) derived from other monomer (x2) than the macromonomer (x1).

[0103] As a specific structure of such a comb-shaped polymer, a copolymer having a side chain containing the structural unit (X1) derived from the macromonomer (x1) relative to the main chain containing the structural unit (X2) derived from the monomer (x2) is preferred.

[0104] Examples of the monomer (x2) include a monomer (x2-a) represented by the following general formula (a1), an alkyl (meth)acrylate (x2-b), a nitrogen atom-containing vinyl monomer (x2-c), a hydroxy group-containing vinyl monomer (x2-d), an aliphatic hydrocarbon-based vinyl monomer (x2-e), an alicyclic hydrocarbon-based vinyl monomer (x2-f), a vinyl ester (x2-g), a vinyl ether (x2-h), a vinyl ketone (x2-i), an epoxy group-containing vinyl monomer (x2-j), a halogen element-containing vinyl monomer (x2-k), an ester of an unsaturated polycarboxylic acid (x2-1), a (di)alkyl fumarate (x2-m), and a (di)alkyl maleate (x2-n).

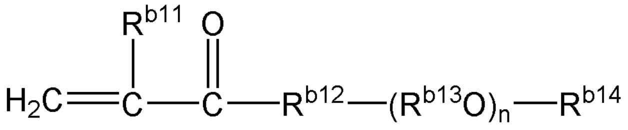
[0105] As the monomer (x2), it is preferred to contain at least one selected from a monomer (x2-a) represented by the following general formula (a1), an alkyl (meth)acrylate (x2-b), and a hydroxy group-containing vinyl monomer (x2-d), and it is more preferred to contain at least a hydroxy group-containing vinyl monomer (x2-d).

[0106] The hydroxy group-containing vinyl monomer (x2-d) serves as a constituent monomer of the aforementioned structural unit (β2).

[0107] In the comb-shaped polymer (B12) that is used in one embodiment of the present invention, the content of the structural unit (β2) 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 1.0 to 15 mol%, and yet still more preferably 1.5 to 10 mol% on the basis of the whole amount (100 mol%) of the structural units of the comb-shaped polymer (B12).

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

[0108]



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

[0109] In the general formula (a1), R^{b11} represents a hydrogen atom or a methyl group.

[0110] R^{b12} represents a single bond, a linear or branched alkylene group having 1 to 10 carbon atoms, -O-, or -NH-.

[0111] R^{b13} represents a linear or branched alkylene group having 2 to 4 carbon atoms. In addition, n represents an integer of 1 or more (preferably an integer of 1 to 20, and more preferably an integer of 1 to 5). In the case where n is an integer of 2 or more, plural R^{b13}'s may be the same as or different from each other, and furthermore, the $(R^{b13}O)_n$ moiety may be either a random bond or a block bond.

[0112] R^{b14} represents a linear or branched alkyl group having a carbon number of 1 to 60 (preferably 10 to 50, and more preferably 20 to 40).

[0113] Specific groups of the aforementioned "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" include the same groups as those exemplified in the descriptions regarding the aforementioned general formulae (i) to (iii).

(Alkyl (Meth)acrylate (x2-b))

[0114] 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.

[0115] The carbon number of the alkyl group which the alkyl (meth)acrylate (x2-b) has is preferably 1 to 30, more preferably 1 to 24, and still more preferably 1 to 18.

[0116] The alkyl group may be a linear alkyl group or may be a branched alkyl group.

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

[0117] 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).

[0118] Examples of the amide group-containing vinyl monomer (x2-c1) include (meth)acrylamide; monoalkylamino (meth)acrylamides, such as N-methyl (meth)acrylamide, N-ethyl (meth)acrylamide, N-isopropyl (meth)acrylamide, N-n-butyl (meth)acrylamide, and isobutyl (meth)acrylamide; monoalkylaminoalkyl (meth)acrylamides, such as N-methylaminoethyl (meth)acrylamide, N-ethylaminoethyl (meth)acrylamide, N-isopropylamino-n-butyl (meth)acrylamide, N-n-butylamino-n-butyl (meth)acrylamide, and isobutylamino-n-butyl (meth)acrylamide; dialkylamino (meth)acrylamides, 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)acrylamides, 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 amides, such as N-vinylformamide, N-vinylacetamide, N-vinyl-n-propionylamide, N-vinyl isopropionylamide, and N-vinylhydroxyacetamide.

[0119] Examples of the nitro group-containing monomer (x2-c2) include nitroethylene and 3-nitro-1-propene.

[0120] Examples of the primary amino group-containing vinyl monomer (x2-c3) include alkenylamines having an alkenyl group having 3 to 6 carbon atoms, such as (meth)allylamine and crotylamine; and aminoalkyl (meth)acrylates having an alkyl group having 2 to 6 carbon atoms, such as aminoethyl (meth)acrylate.

[0121] Examples of the secondary amino group-containing vinyl monomer (x2-c4) include monoalkylaminoalkyl (meth)acrylates, such as t-butylaminoethyl (meth)acrylate and methylaminoethyl (meth)acrylate; and dialkenylamines having 6 to 12 carbon atoms, such as di(meth)allylamine.

[0122] Examples of the tertiary amino group-containing vinyl monomer (x2-c5) include dialkylaminoalkyl (meth)acrylates, such as dimethylaminoethyl (meth)acrylate and diethylaminoethyl (meth)acrylate; alicyclic (meth)acrylates having a nitrogen atom, such as morpholinoethyl (meth)acrylate; and hydrochlorides, sulfates, phosphates, or lower alkyl (carbon number: 1 to 8) monocarboxylic acid (e.g., acetic acid and propionic acid) salts thereof.

[0123] Examples of the nitrile group-containing vinyl monomer (x2-c6) include (meth) acrylonitrile.

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

[0124] 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).

[0125] Examples of the hydroxy group-containing vinyl monomer (x2-d1) include hydroxyalkyl (meth)acrylates 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)acrylamides 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; alkenols having 3 to 12 carbon atoms, such as (meth)allyl alcohol, crotyl alcohol, isocrotyl alcohol, 1-octenol, and 1-undecenol; alkene monools or alkene diols each having 4 to 12 carbon atoms, such as 1-buten-3-ol, 2-buten-1-ol, and 2-butene-1,4-diol; hydroxyalkyl alkenyl ethers 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; compounds in which an unsaturated group, such as an alkenyl group and the aforementioned polymerizable functional group which the macromonomer (x1) has is introduced into a polyhydric alcohol, such as glycerin, pentaerythritol, sorbitol, sorbitan, diglycerin, a sugar, and sucrose; and compounds in which an unsaturated group, such as an alkenyl group and the aforementioned polymerizable functional group which the macromonomer (x1) has is introduced into glyceric acid or a glycerin fatty acid ester.

[0126] Of these, hydroxy group-containing vinyl monomers having two or more hydroxy groups are preferred, and compounds in which an unsaturated group is introduced into a polyhydric alcohol or glyceric acid are more preferred.

[0127] Examples of the polyoxyalkylene chain-containing vinyl monomer (x2-d2) include a polyoxyalkylene glycol (carbon number of the alkylene group: 2 to 4, degree of polymerization: 2 to 50), a polyoxyalkylene polyol (polyoxyalkylene ether of the aforementioned polyhydric alcohol (carbon number of the alkylene group: 2 to 4, degree of polymerization: 2 to 100)), and a mono(meth)acrylate of an alkyl ether (carbon number: 1 to 4) of a polyoxyalkylene glycol or polyoxyalkylene polyol [e.g., 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].

(Aliphatic Hydrocarbon-based Vinyl Monomer (x2-e))

[0128] Examples of the aliphatic hydrocarbon-based vinyl monomer (x2-e) include alkenes having 2 to 20 carbon atoms, such as ethylene, propylene, butene, isobutylene, pentene, heptene, diisobutylene, octene, dodecene, and octadecene; and alkadienes having 4 to 12 carbon atoms, such as butadiene, isoprene, 1,4-pentadiene, 1,6-heptadiene, and 1,7-octadiene.

[0129] The carbon number of the aliphatic hydrocarbon-based vinyl monomer (x2-e) is preferably 2 to 30, more preferably 2 to 20, and still more preferably 2 to 12.

(Alicyclic Hydrocarbon-based Vinyl Monomer (x2-f))

[0130] Examples of the alicyclic hydrocarbon-based vinyl monomer (x2-f) include cyclohexene, (di)cyclopentadiene, pinene, limonene, vinylcyclohexene, and ethylidene bicycloheptene.

[0131] The carbon number of the alicyclic hydrocarbon-based vinyl monomer (x2-f) is preferably 3 to 30, more preferably 3 to 20, and still more preferably 3 to 12.

(Vinyl Ester (x2-g))

[0132] Examples of the vinyl ester (x2-g) include vinyl esters of a saturated fatty acid having 2 to 12 carbon atoms, such as vinyl acetate, vinyl propionate, vinyl butyrate, and vinyl octanoate.

(Vinyl Ether (x2-h))

[0133] Examples of the vinyl ether (x2-h) include alkyl vinyl ethers 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 ethers having 1 to 12 carbon atoms, such as vinyl-2-methoxyethyl ether and vinyl-2-butoxyethyl ether.

(Vinyl Ketone (x2-i))

[0134] Examples of the vinyl ketone (x2-i) include alkyl vinyl ketones having 1 to 8 carbon atoms, such as methyl vinyl ketone and ethyl vinyl ketone.

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

[0135] Examples of the epoxy group-containing vinyl monomer (x2-j) include glycidyl (meth)acrylate and glycidyl (meth)allyl ether.

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

[0136] Examples of the halogen element-containing vinyl monomer (x2-k) include vinyl chloride, vinyl bromide, vinylidene chloride, and (meth)allyl chloride.

(Ester of An Unsaturated Polycarboxylic Acid (x2-1))

[0137] Examples of the ester of an unsaturated polycarboxylic acid (x2-1) include an alkyl ester of an unsaturated polycarboxylic acid, a cycloalkyl ester of an unsaturated polycarboxylic acid, and an aralkyl ester of an unsaturated polycarboxylic acid; and examples of the unsaturated carboxylic acid include maleic acid, fumaric acid, and itaconic acid.

((Di)alkyl Fumarate (x2-m))

[0138] Examples of the (di)alkyl fumarate (x2-m) include monomethyl fumarate, dimethyl fumarate, monoethyl fumarate, diethyl fumarate, methylethyl fumarate, monobutyl fumarate, dibutyl fumarate, dipentyl fumarate, and dihexyl fumarate.

((Di)alkyl Maleate (x2-n))

[0139] Examples of the (di)alkyl maleate (x2-n) include monomethyl maleate, dimethyl maleate, monoethyl maleate, diethyl maleate, methylethyl maleate, monobutyl maleate, and dibutyl maleate.

[0140] The monomer (x2) is preferably a monomer other than a phosphorus atom-containing monomer and an aromatic hydrocarbon-based vinyl monomer.

[0141] In other words, it is preferred that the content of a structural unit derived from a phosphorus atom-containing monomer and the content of a structural unit derived from an aromatic hydrocarbon-based vinyl monomer are low as far as possible.

[0142] The content of the structural unit derived from the phosphorus atom-containing monomer is preferably less than 0.01 mol%, more preferably less than 0.001 mol%, and still more preferably 0 mol% on the basis of the whole amount (100 mol%) of the structural units of the comb-shaped polymer (B12).

[0143] The phosphorus atom-containing monomer refers to a monomer containing a phosphorus atom, and specifically, examples thereof include (meth)acryloyloxyalkyl phosphates, such as (meth)acryloyloxyethyl phosphate and (meth)acryloyloxyisopropyl phosphate; alkenyl phosphates, such as vinyl phosphate, allyl phosphate, propenyl phosphate, isopropenyl phosphate, butenyl phosphate, pentenyl phosphate, octenyl phosphate, decenyl phosphate, and dodecenyl phosphate; (meth)acryloyloxyalkyl phosphonates, such as (meth)acryloyloxyethyl phosphonate; and alkenyl phosphonates, such as vinyl phosphonate, allyl phosphonate, and octenyl phosphonate.

[0144] The content of the structural unit derived from the aromatic hydrocarbon-based vinyl monomer is preferably less than 0.01 mol%, more preferably less than 0.001 mol%, and still more preferably 0 mol% on the basis of the whole amount (100 mol%) of the structural units of the comb-shaped polymer (B12).

[0145] Examples of the aromatic hydrocarbon-based vinyl monomer 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.

<Organic Molybdenum-based Compound (C)>

[0146] It is preferred that the lubricating oil composition according to one embodiment of the present invention contains an organic molybdenum-based compound (C) as a friction modifier.

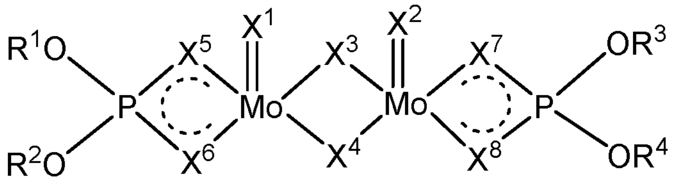
[0147] In the lubricating oil composition according to one embodiment of the present invention, the content of the organic molybdenum-based compound (C) expressed in terms of a molybdenum atom is preferably 400 to 1,000 ppm by mass, more preferably 400 to 950 ppm by mass, still more preferably 400 to 900 ppm by mass, and yet still more preferably 400 to 850 ppm by mass on the basis of the whole amount (100% by mass) of the lubricating oil composition.

[0148] In this specification, the content of the molybdenum atom means a value measured in conformity with JPI-5S-38-92.

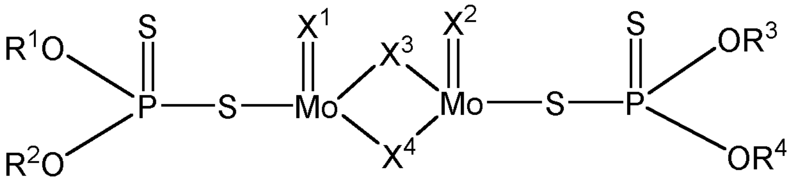
[0149] As the organic molybdenum-based compound (C) that is used in one embodiment of the present invention, though any organic compounds having a molybdenum atom are usable, at least one selected from molybdenum dithiophosphate (MoDTP) and molybdenum dithiocarbamate (MoDTC) is preferred from the viewpoint of improving the friction-reducing effect.

[0150] The organic molybdenum-based compound (C) may be used alone or may be used in combination of two or more thereof.

[0151] As the molybdenum dithiophosphate (MoDTP), a compound represented by the following general formula (c1-1) or a compound represented by the following general formula (c1-2) is preferred.



(c1-1)



(c1-2)

[0152] In the general formulae (c1-1) and (c1-2), R^1 to R^4 each independently represent a hydrocarbon group, and may be the same as or different from each other.

[0153] X^1 to X^8 each independently represent an oxygen atom or a sulfur atom, and may be the same as or different from each other, provided that at least two of X^1 to X^8 in the formula (c1-1) are a sulfur atom.

[0154] In one embodiment of the present invention, in the general formula (c1-1), it is preferred that X^1 and X^2 are an oxygen atom, and X^3 to X^8 are a sulfur atom.

[0155] In the general formula (c1-1), from the viewpoint of improving the solubility, a molar ratio of a sulfur atom to an oxygen atom [(sulfur atom)/(oxygen atom)] in X^1 to X^8 is preferably 1/4 to 4/1, and more preferably 1/3 to 3/1.

[0156] In the general formula (c1-2), it is preferred that X^1 and X^2 are an oxygen atom, and X^3 and X^4 are a sulfur atom.

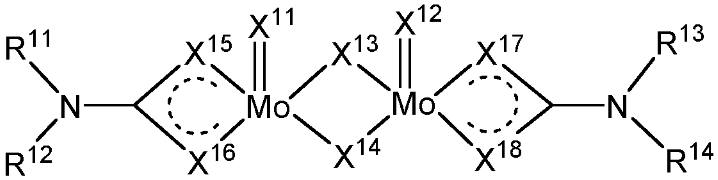
[0157] In the general formula (c1-2), from the same viewpoint as mentioned above, a molar ratio of a sulfur atom to an oxygen atom [(sulfur atom)/(oxygen atom)] in X^1 to X^4 is preferably 1/3 to 3/1, and more preferably 1.5/2.5 to 2.5/1.5.

[0158] The carbon number of the hydrocarbon group which may be selected as R^1 to R^4 is preferably 1 to 20, more preferably 5 to 18, still more preferably 5 to 16, and yet still more preferably 5 to 12.

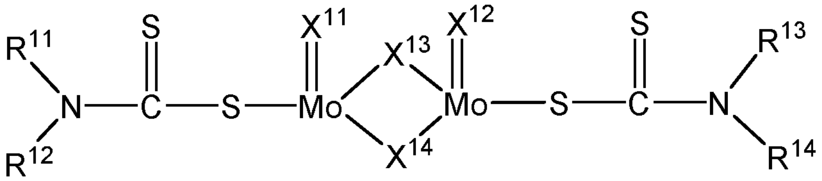
[0159] Specifically, examples of the hydrocarbon group which may be selected as R^1 to R^4 include an alkyl group, such as a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a nonyl group, a decyl group, an undecyl group, a dodecyl group, a tridecyl group, a tetradecyl group, a pentadecyl group, a hexadecyl group, a heptadecyl group, and an octadecyl group; an alkenyl group, such as an octenyl group, a nonenyl group, a decenyl group, an undecenyl group, a dodecenyl group, a tridecenyl group, a tetradecenyl group, and a pentadecenyl group; a cycloalkyl group, such as a cyclohexyl group, a dimethylcyclohexyl group, an ethylcyclohexyl group, a methylcyclohexylmethyl group, a cyclohexylethyl group, a propylcyclohexyl group, a butylcyclohexyl group, and a heptylcyclohexyl group; an aryl group, such as a phenyl group, a naphthyl group, an anthracenyl group, a biphenyl group, and a terphenyl group; an alkylaryl group, such as a tolyl group, a dimethylphenyl group, a butylphenyl group, a nonylphenyl group, a methylbenzyl group, and a dimethylnaphthyl group; and an arylalkyl group, such as a phenylmethyl group, a phenylethyl group, and a diphenylmethyl group.

[0160] Examples of the molybdenum dithiocarbamate (MoDTC) include a binuclear molybdenum dithiocarbamate having two molybdenum atoms in one molecule thereof; and a trinuclear molybdenum dithiocarbamate having three molybdenum atoms in one molecule thereof, with a binuclear molybdenum dithiocarbamate being preferred.

[0161] As the binuclear molybdenum dithiocarbamate, a compound represented by the following general formula (c2-1) and a compound represented by the following general formula (c2-2) are more preferred.



(c2-1)



(c2-2)

[0162] In the general formulae (c2-1) and (c2-2), R^{11} to R^{14} each independently represent a hydrocarbon group, and may be the same as or different from each other.

[0163] X^{11} to X^{18} each independently represent an oxygen atom or a sulfur atom, and may be the same as or different from each other.

[0164] However, at least one of X^{11} to X^{18} in the formula (c2-1) is a sulfur atom.

[0165] In one embodiment of the present invention, in the formula (c2-1), it is preferred that X^{11} and X^{12} are an oxygen atom, and X13 to X^{18} are a sulfur atom.

[0166] In the general formula (c2-1), from the viewpoint of improving the solubility in the base oil (A), a molar ratio of a sulfur atom to an oxygen atom [(sulfur atom)/(oxygen atom)] in X^{11} to X^{18} is preferably 1/4 to 4/1, and more preferably 1/3 to 3/1.

[0167] It is preferred that X^{11} to X^{14} in the formula (b2-2) are an oxygen atom.

[0168] In the general formulae (c2-1) and (c2-2), the carbon number of the hydrocarbon group which may be selected as R^{11} to R^{14} is preferably 1 to 20, more preferably 5 to 18, still more preferably 5 to 16, and yet still more preferably 5 to 13.

[0169] As the specific hydrocarbon group which may be selected as R^{11} to R^{14}, there are exemplified the same hydrocarbon groups as the hydrocarbon groups which may be selected as R^1 to R^4 in the general formulae (c1-1) and (c1-2).

<Additive for Lubricating Oil>

[0170] The lubricating oil composition according to one embodiment of the present invention may further contain an additive for a lubricating oil other than the components (B) and (C) (hereinafter also referred to simply as "additive for lubricating oil"), as required, within a range where the effects of the present invention are not impaired.

[0171] Examples of such an additive for lubricating oil include a pour-point depressant, a metal-based detergent, a dispersant, an anti-wear agent, an extreme pressure agent, an antioxidant, an anti-foaming agent, a rust inhibitor, and a metal deactivator.

[0172] A commercially available additive package containing a plurality of additives and meeting API/ILSAC SN/GF-5 standards or the like may be used as an additive for lubricating oil.

[0173] A compound having plural functions as the additive (for example, a compound having functions as an anti-wear agent and an extreme pressure agent) may also be used.

[0174] Furthermore, the respective additives for lubricating oil may be used alone or may be used in combination of two or more thereof.

[0175] Although the content of each of such additives for lubricating oil can be appropriately regulated within a range where the effects of the present invention are not impaired, it is typically 0.001 to 15% by mass, preferably 0.005 to 12% by mass, and more preferably 0.01 to 10% by mass on the basis of the whole amount (100% by mass) of the lubricating oil composition independently for every additive.

[0176] In the lubricating oil composition according to one embodiment of the present invention, a total content of these additives for lubricating oil is preferably 0 to 40% by mass, more preferably 0 to 30% by mass, still more preferably 0 to 20% by mass, and yet still more preferably 0 to 15% by mass on the basis of the whole amount (100% by mass) of the lubricating oil composition.

[Various Physical Properties of Lubricating Oil Composition]

[0177] A kinematic viscosity at 40°C of the lubricating oil composition according to one embodiment of the present invention is preferably 12.0 to 45.0 mm^2/s, more preferably 15.0 to 40.0 mm^2/s, and still more preferably 20.0 to 37.0 mm^2/s.

[0178] A kinematic viscosity at 80°C of the lubricating oil composition according to one embodiment of the present invention is preferably 5.0 to 15.0 mm^2/s, more preferably 6.5 to 14.0 mm^2/s, and still more preferably 8.0 to 13.0 mm^2/s.

[0179] A kinematic viscosity at 100°C of the lubricating oil composition according to one embodiment of the present invention is preferably 2.0 to 12.0 mm^2/s, more preferably 3.0 to 10.0 mm^2/s, and still more preferably 5.0 to 9.0 mm^2/s. In addition, it is preferably 6.1 mm^2/s or more and less than 12.5 mm^2/s, more preferably 6.1 mm^2/s or more and 11.5 mm^2/s or less, and still more preferably 6.1 mm^2/s or more and 11.0 mm^2/s or less.

[0180] A viscosity index of the lubricating oil composition according to one embodiment of the present invention is preferably 120 or more, more preferably 140 or more, still more preferably 170 or more, and yet still more preferably 190 or more.

[0181] From the viewpoint of providing a lubricating oil composition having favorable fuel consumption reducing properties in use in a temperature environment at around 80°C assuming a practical region of the engine, an HTHS viscosity (high temperature high shear viscosity) at 80°C of the lubricating oil composition according to one embodiment of the present invention is preferably 4.0 to 8.2 mPa·s, more preferably 4.3 to 8.0 mPa·s, and still more preferably 4.7 to 7.8 mPa·s.

[0182] The HTHS viscosity is also called a TBS viscosity.

[0183] From the viewpoint of providing a lubricating oil composition having favorable fuel consumption reducing properties at the time of high-temperature operation, the HTHS viscosity at 150°C of the lubricating oil composition according to one embodiment of the present invention is preferably 2.4 to 5.5 mPa·s, more preferably 2.5 to 5.0 mPa·s, and still more preferably 2.6 to 4.5 mPa·s. In addition, it is 2.3 mPa·s or more and less than 2.9 mPa·s, more preferably 2.3 mPa·s or more and 2.8 mPa·s or less, and still more preferably 2.3 mPa·s or more and 2.7 mPa·s or less.

[0184] In this specification, the HTHS viscosity means a value measured in conformity with ASTM D4683.

[Production Method of Lubricating Oil Composition]

[0185] Although the method for producing the lubricating oil composition of the present invention is not particularly limited, a production method including the following step (1) is preferred.

Step (1): A step of blending a base oil (A) with a viscosity index improver (B) in which a ratio [$\Delta|\alpha(40)|/\Delta|\alpha(100)|$] between $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ as calculated through the following operations (i) to (iii) is 1.5 or more:

- Operation (i): a sample oil having the viscosity index improver (B) dissolved in a mineral oil is prepared, and the X-ray small-angle scattering measurement is performed under a temperature condition at 40°C and 100°C, respectively, to acquire X-ray small-angle scattering spectra (x axis: scattering vector q (nm^{-1}), y axis: common logarithm log (I) of scattering intensity I);
- Operation (ii): in the X-ray small-angle scattering spectrum at 40°C as obtained in the operation (i), an absolute value $\Delta|\alpha(40)|$ of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method; and
- Operation (iii): in the X-ray small-angle scattering spectrum at 100°C as obtained in the operation (i), an absolute value $\Delta|\alpha(100)|$ of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method.

[0186] In the step (1), the mineral oil (A) and the viscosity index improver (B) are those as mentioned above, and the preferred components and the contents of the respective components are also those as mentioned above.

[0187] In the present step, the aforementioned additive for lubricating oil other than the mineral oil (A) and the viscosity index improver (B) may also be blended.

[0188] The viscosity index improver (B) may be blended in a form of a solution dissolved in a diluent oil. A solid component concentration of the solution is typically 10 to 50% by mass.

[0189] It is preferred that after blending the respective components, the resulting blend is stirred and uniformly dispersed by a known method.

[Application of Lubricating Oil Composition]

[0190] The lubricating oil composition of the present invention is able to stably reveal excellent fuel consumption reducing properties even in use in a wide temperature environment of from a low-temperature region to a high-temperature region.

[0191] Accordingly, the lubricating oil composition of the present invention is preferably used as an engine oil.

[0192] Examples of engines which are suitable for use of the lubricating oil composition of the present invention include engines for vehicles, such as automobiles, electric trains, and aircrafts. Preferred are automobile engines, and more preferred are automobile engines equipped with a hybrid mechanism or a start-up system.

[0193] Although the lubricating oil composition according to one embodiment of the present invention is suitable for uses as a lubricating oil composition for internal combustion engines of vehicles, such as automobiles, electric trains, and aircrafts (engine oils for internal combustion engines), it is also applicable for other uses.

[Engine]

[0194] The present invention also provides an engine containing the aforementioned lubricating oil composition of the present invention.

[0195] The foregoing engine is one as mentioned above.

[0196] The lubricating oil composition of the present invention is able to stably reveal excellent fuel consumption reducing properties even in use in a wide temperature environment of from a low-temperature region to a high-temperature region. In consequence, in accordance with the engine of the present invention, excellent fuel consumption reducing properties may be stably revealed even in use in a wide temperature environment of from a low-temperature region to a high-temperature region.

[Lubrication Method of Engine]

[0197] The present invention also provides a lubrication method of an engine, including lubricating the engine with the aforementioned lubricating oil composition of the present invention.

[0198] The foregoing engine is one as mentioned above.

[0199] The lubricating oil composition of the present invention is able to stably reveal excellent fuel consumption reducing properties even in use in a wide temperature environment of from a low-temperature region to a high-temperature region. In consequence, in accordance with the lubricating method of an engine of the present invention, excellent fuel consumption reducing properties may be stably given to an engine in a wide temperature environment of from a low-temperature region to a high-temperature region.

Examples

[0200] Next, the present invention is described in more detail by reference to Examples, but it should be construed that the present invention is by no means limited by these Examples. The measurement methods and evaluation methods of various physical properties are as follows.

(1) Kinematic viscosity at each of 40°C, 80°C, and 100°C and viscosity index

[0201] The measurement and calculation were performed in conformity with JIS K2283:2000.

(2) Weight average molecular weight (Mw) and number average molecular weight (Mn)

[0202] Using a gel permeation chromatograph apparatus ("1260 Model HPLC", manufactured by Agilent), the measurement was performed under the following condition, and a value expressed in terms of standard polystyrene was adopted.

(Measuring Condition)

[0203]

- Column: One in which two of "Shodex LF404" are successively connected to each other
- Column temperature: 35°C
- Developing solvent: Chloroform
- Flow rate: 0.3 mL/min

(3) Content of molybdenum atom

[0204] The measurement was performed in conformity with JPI-5S-38-92.

(4) HTHS viscosity (high temperature high shear viscosity) at each of 80°C and 150°C

[0205] The measurement was performed at a shear rate of 10^6/s under a predetermined temperature condition at 80°C or 150°C by using a TBS high-temperature viscometer (tapered bearing simulator viscometer) in conformity with ASTM D4683.

[0206] Viscosity index improvers (1) to (5) used in the following Examples and Comparative Examples are as follows.

- Viscosity index improver (1): A comb-shaped polymer having structural units derived from methyl acrylate, a hydrogenated polybutadiene (which is a monomer corresponding to the macromonomer (x1) and constituting the structural unit (β1), Mn = 4,000 or more), 2-ethylhexyl acrylate, and a compound having an unsaturated group introduced into glyceric acid (corresponding to the hydroxy group-containing vinyl monomer (x2-d)). Content of the structural unit derived from the hydrogenated polybutadiene relative to the whole amount (100 mol%) of the structural units of the foregoing comb-shaped polymer = 1 mol%, Mw = 550,000, Mw/Mn = 1.8.
- Viscosity index improver (2): A styrene-isoprene-butadiene copolymer (styrene/isoprene/butadiene = 18/73/9 (mol%)). Mw = 640,000, Mw/Mn = 1.2.
- Viscosity index improver (3): A comb-shaped polymer having structural units derived from methyl acrylate and a hydrogenated polybutadiene (which is a monomer corresponding to the macromonomer (x1) and constituting the structural unit (β1), Mn = 2,000 or more). Content of the structural unit derived from the hydrogenated polybutadiene relative to the whole amount (100 mol%) of the structural units of the foregoing comb-shaped polymer = 1 mol%, Mw = 450,000, Mw/Mn = 5.2.
- Viscosity index improver (4): A styrene-isoprene copolymer (styrene/isoprene = 27/73 (mol%)). Mw = 130,000, Mw/Mn = 1.0.
- Viscosity index improver (5): Polymethyl acrylate (homopolymer composed of methyl acrylate). Mw = 400,000, Mw/Mn = 2.0.

[0207] Each of these viscosity index improvers (1) to (5) was dissolved in a mineral oil (paraffinic mineral oil which is a mineral oil classified into Group 3 of the base stock categories of the API, kinematic viscosity at 40°C = 17.9 mm^2/s, kinematic viscosity at 100°C = 4.16 mm^2/s, viscosity index = 134), to prepare a sample oil. The viscosity index improver was blended such that the kinematic viscosity at 100°C of each of the sample oils fell within a range of 7.8 to 8.2 mm^2/s.

[0208] Using a small angle X-ray scattering device (manufactured by Anton Paar GmbH, a product name: "SAX-SPACE"), a quartz capillary having the sample oil charged therein was placed in a sample holder provided with a temperature controller of the small angle X-ray scattering device, heated at 40°C and 100°C, respectively, and then subjected to X-ray small-angle scattering measurement, to acquire X-ray small-angle scattering spectra (x axis: scattering vector q (nm^{-1}), y axis: common logarithm log (I) of scattering intensity I).

[0209] Then, in the X-ray small-angle scattering spectrum at 40°C, an absolute value $\Delta|\alpha(40)|$ of a slope of a straight line was calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method.

[0210] In addition, similarly, in the X-ray small-angle scattering spectrum at 100°C, an absolute value $\Delta|\alpha(100)|$ of a slope of a straight line was calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method.

[0211] Finally, a ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ between $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ was calculated. These values are those shown in Table 1.

Table 1

	Viscosity index improver (1)	Viscosity index improver (2)	Viscosity index improver (3)	Viscosity index improver (4)	Viscosity index improver (5)
Characteristic feature on structure	Comb-shaped polymer	Styrene/isoprene/ butadiene copolymer	Comb-shaped polymer	Styrene/ isoprene copolymer	Polymethyl acrylate

(continued)

		Viscosity index improver (1)	Viscosity index improver (2)	Viscosity index improver (3)	Viscosity index improver (4)	Viscosity index improver (5)
Structural unit		Methyl acrylate Hydrogenated polybutadiene 2-Ethylhexyl acrylate Glyceric acid (*1)	Styrene: 18 mol% Isoprene: 73 mol% Butadiene: 9 mol%	Methylacrylate Hydrogenated polybutadiene	Styrene: 27 mol % Isoprene: 73 mol%	Methyl acrylate
Mw	-	550,000	640,000	450,000	130,000	400,000
Mw/Mn	-	1.8	1.2	5.2	1.0	2.0
$\Delta\alpha(40)|$	[1/ (nm^{-1})]	4.12	4.23	2.94	4.15	1.59
$\Delta|\alpha(100)|$	[1/ (nm^{-1})]	2.16	2.63	1.73	3.96	1.15
$[\Delta\alpha(40)|/\Delta|\alpha(100)|]$		1.91	1.61	1.70	1.05	1.38
(*1) Compound having an unsaturated group introduced into glyceric acid						

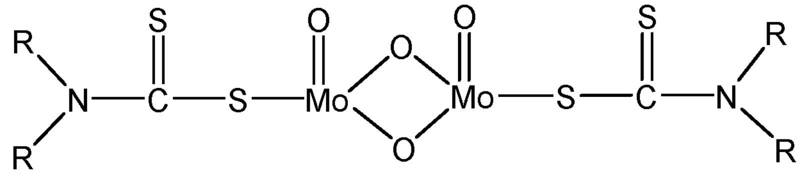
Examples 1 to 3 and Comparative Examples 1 to 2

[0212] To a base oil, any one of the viscosity index improvers (1) to (5), a pour-point depressant, a friction modifier, and an additive package for engine oil were added in a blending amount shown in Table 2, to prepare each lubricating oil composition.

[0213] In the case of being diluted with a diluent oil, the content of each of the respective viscosity index improvers (1) to (5), the pour-point depressant, the friction modifier, and the additive package for engine oil shown in Table 2 is the content expressed in terms of the active component (expressed in terms of the resin component) in which the diluent oil is eliminated.

[0214] Details of the used base oil, pour-point depressant, friction modifier, and additive package for engine oil are described below, and details of the viscosity index improvers (1) to (5) are those as mentioned above.

· Base oil: Paraffinic mineral oil which is a mineral oil classified into Group 3 of the base stock categories of the API, kinematic viscosity at 40°C = 17.9 mm^2/s, kinematic viscosity at 100°C = 4.16 mm^2/s, viscosity index = 134.
· Pour-point depressant: Polymethacrylate of Mw = 70,000.
· Friction modifier: ADEKA SAKURA-LUBE 515 (manufactured by Adeka Corporation); content of molybdenum atom = 10.0% by mass; content of sulfur atom = 11.5% by mass. A binuclear molybdenum dialkyldithiocarbamate (MoDTC) represented by the following formula:



[0215] In the formula, R's are each independently a hydrocarbon group having 8 or 13 carbon atoms.
· Additive package for engine oil: An additive package adapted to the API/ILSAC standards and the SN/GF-5 standards and containing the following various additives.

Metal-based detergent: Calcium salicylate

Dispersant: Macromolecular bisimide and boron-modified monoimide

Anti-wear agent: Primary ZnDTP and secondary ZnDTP

Antioxidant: Diphenylamine-based antioxidant and hindered phenol-based antioxidant

Metal deactivator: Benzotriazole

Anti-foaming agent: Silicone-based anti-foaming agent

[0216] With respect to the prepared lubricating oil compositions, the kinematic viscosity, the viscosity index, the HTHS viscosity were measured or calculated in conformity with the aforementioned methods, as well as a driving torque improving rate of each of the lubricating oil compositions at an oil temperature of each of 40°C and 80°C was evaluated on the basis of the following method. These results are shown in Table 2.

[Measurement of Driving Torque Improving Rate]

[0217] A crankshaft of an in-line four-cylinder engine (valve operating system: roller valve operation type) having a displacement of 1.5 L was driven by a motor, and on that occasion, a torque applied to the crankshaft was measured. The measurement was performed in the case where a number of revolutions of the crankshaft was 1,600 rpm, and an engine oil temperature was 40°C and 80°C, respectively.

[0218] A measured value of a torque when using a lubricating oil composition of Comparative Example 2 was made as a basis, and a driving torque improving rate (%) on the occasion of using each of the lubricating oil compositions other than that of Comparative Example 2 was calculated according to the following equation.

· [Driving torque improving rate] (%) = {([Measured value of torque when the lubricating oil composition of Comparative Example 2 was used] - [Measured value of torque when the lubricating oil as an object was used])/[Measured value of torque when the lubricating oil composition of Comparative Example 2 was used]} × 100

[0219] It is expressed that in the case where the value of the driving torque improving rate calculated from the aforementioned equation is plus, the fuel consumption reducing properties are higher than those of the lubricating oil composition of Comparative Example 2, whereas it is expressed that in the case where the value of the driving torque improving rate is minus, the fuel consumption reducing properties are inferior to those of the lubricating oil composition of Comparative Example 2.

[0220] In other words, it may be said that as the value of the driving torque improving rate calculated from the aforementioned equation is large, the driving torque is improved, and the fuel consumption reducing properties of the lubricating oil composition as a measurement object are high.

[0221] In the present Examples, though the driving torque improving rate at 40°C of 0.5% or more is considered as passing, it is preferably 1.0% or more, and more preferably 2.0% or more.

[0222] In addition, the driving torque improving rate at 80°C of 0.1% or more is considered as passing, and it is preferably 0.12% or more, and more preferably 0.14% or more.

Table 2

			Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2
Composition	Base oil	% by mass	88.20	87.40	88.21	87.10	88.05
	Viscosity index improver (1) $[\Delta\vert\alpha(40)\vert/\Delta\vert\alpha(100)\vert] = 1.91$	% by mass	2.00	-	-	-	-
	Viscosity index improver (2) $[\Delta\vert\alpha(40)\vert/\Delta\vert\alpha(100)\vert] = 1.61$	% by mass	-	2.80	-	-	-
	Viscosity index improver (3) $[\Delta\vert\alpha(40)\vert/\Delta\vert\alpha(100)\vert] = 1.70$	% by mass	-	-	1.99	-	-
	Viscosity index improver (4) $[\Delta\vert\alpha(40)\vert/\Delta\vert\alpha(100)\vert] = 1.05$	% by mass	-	-	-	3.10	-
	Viscosity index improver (5) $[\Delta\vert\alpha(40)\vert/\Delta\vert\alpha(100)\vert] = 1.38$	% by mass	-	-	-	-	2.15
	Pour-point depressant	% by mass	0.20	0.20	0.20	0.20	0.20
	Friction modifier	% by mass	0.70	0.70	0.70	0.70	0.70
	Additive package for engine oil	% by mass	8.90	8.90	8.90	8.90	8.90
	Total	% by mass	100.00	100.00	100.00	100.00	100.00
	Content of Mo atom	ppm by mass	700	700	700	700	700

(continued)

			Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2
Various physical properties	Kinematic viscosity at 40°C	mm^2/s	27.79	36.54	30.11	45.84	36.19
	Kinematic viscosity at 80°C	mm^2/s	10.66	12.43	11.73	13.97	12.07
	Kinematic viscosity at 100°C	mm^2/s	7.45	8.36	8.23	9.08	8.08
	Viscosity index	-	256	216	269	184	207
	HTHS viscosity at 80°C	mPa·s	6.86	7.69	7.26	7.99	7.88
	HTHS viscosity at 150°C	mPa·s	2.60	2.64	2.63	2.64	2.60
	Driving torque improving rate at 40°C	%	5.23	2.27	3.73	-2.61	Basis
	Driving torque improving rate at 80°C	%	2.61	0.15	1.31	-1.22	Basis

[0223] There were revealed results such that the lubrication oil compositions prepared in Examples 1 to 3 are excellent in the fuel consumption reducing properties in a temperature environment at around 40°C assuming an initial motion region of the engine and in a temperature environment at around 80°C assuming a practical use region of the engine, as compared with the lubricating oil compositions of Comparative Examples 1 to 2.

Claims

1. A lubricating oil composition comprising a base oil (A) and a viscosity index improver (B) in which a ratio $[\Delta|\alpha(40)|/\Delta|\alpha(100)|]$ between $\Delta|\alpha(40)|$ and $\Delta|\alpha(100)|$ as calculated through the following operations (i) to (iii) is 1.5 or more:

    · Operation (i): a sample oil having the viscosity index improver (B) dissolved in a mineral oil is prepared, and the X-ray small-angle scattering measurement is performed under a temperature condition at 40°C and 100°C, respectively, to acquire X-ray small-angle scattering spectra (x axis: scattering vector q (nm^{-1}), y axis: common logarithm log (I) of scattering intensity I);
    · Operation (ii): in the X-ray small-angle scattering spectrum at 40°C as obtained in the operation (i), an absolute value $\Delta|\alpha(40)|$ of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method; and
    · Operation (iii): in the X-ray small-angle scattering spectrum at 100°C as obtained in the operation (i), an absolute value $\Delta|\alpha(100)|$ of a slope of a straight line is calculated in a range of the scattering vector q as the x axis of from 0.1 nm^{-1} to 1 nm^{-1} by the least-squares method.

2. The lubricating oil composition according to claim 1, wherein the base oil (A) contains a mineral oil.

3. The lubricating oil composition according to claim 2, wherein the mineral oil is a mineral oil classified into Group 2 or Group 3 of the base stock categories of the API (American Petroleum Institute).

4. The lubricating oil composition according to any one of claims 1 to 3, wherein the viscosity index improver (B) contains a polymer (B1) having a structural unit (β1) derived from a monomer selected from butadiene and hydrogenated butadiene.

5. The lubricating oil composition according to claim 4, wherein the content of the structural unit (β1) is 0.1 to 70 mol% relative to the whole amount of the structural units of the polymer (B1).

6. The lubricating oil composition according to claim 4 or 5, wherein the polymer (B1) is at least one selected from a styrene-isoprene-butadiene copolymer (B11) and a comb-shaped polymer (B12).

7. The lubricating oil composition according to any one of claims 1 to 6, wherein a weight average molecular weight of the viscosity index improver (B) is 100,000 to 900,000.

8. The lubricating oil composition according to any one of claims 1 to 7, wherein the content of the viscosity index improver (B) expressed in terms of a resin component is 0.5 to 8.0% by mass on the basis of the whole amount of the lubricating oil composition.

9. The lubricating oil composition according to any one of claims 1 to 8, which is used for engines.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/010032

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. C10M169/04(2006.01)i, C10M101/02(2006.01)n,
C10M143/12(2006.01)n, C10N20/00(2006.01)n, C10N20/04(2006.01)n,
C10N30/00(2006.01)n, C10N30/08(2006.01)n, C10N40/25(2006.01)n

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, C10M101/02, C10M143/12, C10N20/00, C10N20/04,
C10N30/00, C10N30/08, C10N40/25

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	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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

JSTPlus/JMEDPlus/JST7580 (JDreamIII) キーワード：エンジン油，粘度指数向上剤，X線スペクトル及びそれに類する用語

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2014-210844 A (COSMO OIL LUBRICANTS CO., LTD.) 13 November 2014, claims, paragraphs [0049]-[0064], example 1 (Family: none)	1-9
X	JP 2017-43734 A (COSMO OIL LUBRICANTS CO., LTD.) 02 March 2017, claims, paragraphs [0058]-[0071], examples 1-3 (Family: none)	1-9
X	JP 2013-536293 A (TOTAL RAFFINAGE MARKETING) 19 September 2013, claims, paragraphs [0104]-[0139], example A & US 2013/0196888 A1 claims, paragraphs [0061]-[0088], example A & WO 2012/025901 A1 & EP 2609180 A1 & CN 103097503 A	1-9

☒ 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
"E"	earlier application or patent but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search 07 May 2019 (07.05.2019)	Date of mailing of the international search report 21 May 2019 (21.05.2019)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/010032

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2012-92334 A (AFTON CHEMICAL CORPORATION) 17 May 2012, claims, paragraphs [0029]-[0045], examples, etc. & US 2012/0101017 A1 claims, paragraphs [0029]-[0050], examples, etc. & EP 2444475 A1 & CN 102453588 A	1-9
X	JP 2017-119787 A (SHOWA SHELL SEKIYU KK.) 06 July 2017, claims, paragraphs [0025]-[0060], example 6, etc. & WO 2017/114836 A1 claims, page 11, line 21 to page 24, example 6, etc. & EP 3397740 A1 & CN 108431188 A	1-9
X	WO 2016/043334 A1 (IDEMITSU KOSAN CO., LTD.) 24 March 2016, claims, paragraphs [0073], [0111]-[0122], examples, etc. & US 2017/0137732 A1 claims, paragraphs [0131], [0200]-[0236], examples, etc. & EP 3196279 A1 & CN 106459821 A	1-9
X	WO 2016/043333 A1 (IDEMITSU KOSAN CO., LTD.) 24 March 2016, claims, paragraphs [0060], [0144]-[0170], examples, etc. & US 2017/0298287 A1 claims, paragraphs [0114], [0260]-[0298], examples, etc. & EP 3196278 A1 & CN 107075405 A	1-9
X	WO 2017/164319 A1 (IDEMITSU KOSAN CO., LTD.) 28 September 2017, claims, paragraphs [0104], [0165]-[0175], examples, etc. & CN 108779414 A	1-9
P, X	JP 2019-14802 A (NIPPON SHOKUBAI CO., LTD.) 31 January 2019, claims, paragraphs [0093]-[0138], examples 1-3 (Family: none)	1-9
E, X	JP 2019-44186 A (EVONIK OIL ADDITIVES GMBH) 22 March 2019, claims, paragraphs [0176]-[0214], examples, etc. & US 2019/071615 A1 claims, paragraphs [0246]-[0280], examples, etc. & EP 3450527 A1	1-9

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2007217494 A **[0005]**