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(71) Applicant: **ENEOS Corporation**
Chiyoda-ku
Tokyo 100-8162 (JP)

(72) Inventors:
- **HOSHINO Koji**
  Tokyo 100-8162 (JP)
- **KUSUHARA Shintaro**
  Tokyo 100-8162 (JP)
- **MUTOU Akio**
  Tokyo 100-8162 (JP)
- **MATSUDA Hiromitsu**
  Tokyo 100-8162 (JP)

(74) Representative: **Müller-Boré & Partner**
Patentanwälte PartG mbB
Friedenheimer Brücke 21
80639 München (DE)

(54) LUBRICANT COMPOSITION

(57) [Problem to be solved] To provide a lubricating oil composition for a supercharged engine, which is capable of having a good balance of caulking resistance, LSPI suppression performance, and high-temperature cleaning properties.

[Means to solve the problem] The lubricating oil composition for a supercharged engine according to the present invention is characterized by comprising:
(A) a lubricating oil base oil;
(B) a calcium-based cleaning agent, wherein the calcium amount is 1100 mass ppm or more to 1900 mass ppm or less on a total amount basis of the lubricant composition;
(C) a magnesium-based cleaning agent; and
(D) at least one viscosity index improver selected from a styrene-diene copolymer and an ethylene-α-olefin copolymer; and
(E) a nitrogen-containing dispersing agent;
and containing 700 mass ppm or more of nitrogen component, on a total amount basis of the lubricating oil composition.

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Description

[Field of the Invention]

[0001] The present invention relates to a lubricating oil composition, and more particularly to a lubricating oil composition for an internal combustion engine, and more particularly to a lubricating oil composition for a supercharged engine.

[Background Art]

[0002] Automobile internal combustion engines have been receiving various requisitions to be small in size and high in output, to be fuel-efficient, and to comply with exhaust gas regulations in recent years, and various lubricating oil compositions for internal combustion engines for the purpose of fuel efficiency have been studied. In particular, in order to reduce the fuel consumption of the automobile internal combustion engines, there has been proposed to replace a conventional naturally aspirated gasoline engine with an engine having a lower displacement with a supercharger (a supercharged downsizing engine). In a supercharged downsize engine, it is possible to reduce the displacement while maintaining the output and achieve fuel efficiency by providing a supercharger. On the other hand, when the torque is increased in a low rotational speed range in the supercharging downsize engine, there may be a phenomenon in which ignition occurs in the cylinder earlier than the scheduled timing (LSPI: Low Speed Pre-Ignition). When LSPI occurs, energy loss increases which not only limits the improvement in fuel efficiency and enhancement in the low speed torque but leads to damaging of the engine.

[0003] In the above-described lubricating oil composition for an internal combustion engine, various additives are added such as an anti-wear agent, a metal cleaning agent, an ashless dispersing agent, and an antioxidant in a lubricating base oil, in order to satisfy various performances (see Patent Document 1). Since the effect of the lubricating oil is suspected in the occurrence of the LSPI, the lubricating oil is required to have a function of suppressing the occurrence of the LSPI. However, for example, when the amount of a calcium-based cleaning agent is reduced in order to reduce the occurrence frequency of the LSPI, the cleaning dispersibility of the lubricating oil composition tends to decline.

[0004] It is believed that additives containing molybdenum or phosphorus tend to reduce the frequency of occurrence of LSPI, but friction modifiers containing molybdenum and anti-wear agents containing phosphorus may decompose at high temperatures and turn into deposits. Therefore, if the amount of friction modifiers containing molybdenum or anti-wear agents containing phosphorus is increased to reduce the frequency of occurrence of LSPI, there is a problem that cleaning properties at high-temperature are reduced. That is, the technique for preventing the LSPI and the technique for ensuring the performance required for the lubricating oil composition may be self-contradictory, and there is a need for a technique to achieve both together. Therefore, in order to reduce the frequency of occurrence of LSPI, there is proposed a lubricating oil composition in which the amounts of calcium, magnesium, molybdenum and phosphorus satisfy a specific relation, and the amounts of calcium and magnesium and the amount of nitrogen derived from an ashless dispersing agent satisfy a specific relation (see Patent Document 2).

[Prior Art Documents]

[0005]

Patent Document 1: Japanese Unexamined Patent Publication No. 2003-155492
Patent Document 2: Japanese Unexamined Patent Publication No. 2015-163673

[Outline of the Invention]

[Problems to be Solved by the Invention]

[0006] In recent years, lubricating oils are required for further caulking resistance (heat resistance) as caulking in superchargers has become a more serious problem, accompanied by the reducing of viscosity in lubricating oils, and superchargers for diesel engines are more susceptible to high temperatures than the gasoline engines.

[0007] However, as a result of examining the invention described in Patent Document 2, the present inventors have found that in a lubricating oil composition in which a calcium-based cleaning agent and a magnesium-based cleaning agent are used in combination, caulking resistance was insufficient when poly(meth)acrylate was used as a viscosity index improver. Accordingly, it is an object of the present invention to provide a lubricating oil composition for supercharged engines, which can provide a good balance of caulking resistance, LSPI-suppressing performance, and high-temperature cleaning properties.

[Means for Solving the Problem]

[0008] As a result of intensive studies to solve the above problem, the present inventors have found that the above problem can be solved by using a specific polymer as a viscosity index improver in a lubricating oil composition in which a calcium-based cleaning agent and a magnesium-based cleaning agent are used in combination and adjusting the amount of nitrogen within a specific range, and thus have completed the present invention.

[0009] That is, according to the present invention, the following invention is provided.

[1] A lubricating oil composition for a super-charged engine, comprising:

(A) a lubricating oil base oil;
(B) a calcium-based cleaning agent, wherein the calcium amount is 1100 mass ppm or more to 1900 mass ppm or less on a total amount basis of the lubricant oil composition;
(C) a magnesium-based cleaning agent; and
(D) at least one viscosity index improver selected from a styrene-diene copolymer and an ethylene-α-olefin copolymer; and
(E) a nitrogen-containing dispersing agent;

and containing 700 mass ppm or more of a nitrogen component, on a total amount basis of the lubricating oil composition.

[2] The lubricating oil composition according to [1], wherein the (B) calcium-based cleaning agent is calcium salicylate.

[3] The lubricating oil composition according to [1] or [2], wherein the (C) magnesium-based cleaning agent is magnesium salicylate.

[4] The lubricating oil composition according to any one of [1] to [3], wherein the content of the (C) magnesium-based cleaning agent is 100 ppm by mass or more to 1000 ppm by mass or less as a magnesium amount on a total amount basis of the lubricating oil composition.

[5] The lubricating oil composition according to any one of [1] to [4], wherein the viscosity index improver (D) is a styrene-diene copolymer.

[6] The lubricating oil composition according to any one of [1] to [5], wherein the content of the (D) viscosity index improver is 0.1% by mass or more to 20% by mass or less on a total amount basis of the lubricating oil composition.

[7] The lubricating oil composition according to any one of [1] to [6], further comprising (F) an ashless friction modifier.

[8] The lubricating oil composition according to any one of [1] to [7], further comprising (G) a molybdenum-containing compound.

[9] The lubricating oil composition according to any one of [1] to [8], further comprising zinc alkylphosphate as (H) an anti-wear agent.

[10] The lubricating oil composition according to any one of [1] to [9], wherein the kinematic viscosity at 100 °C is 4.0mm^2 / s or more and less than 12.5mm^2 / s.

[11] The lubricating oil composition according to any one of [1] to [10], wherein the HTHS viscosity at 150 °C is 1.7 mPa·s or more and less than 3.5 mPa·s.

[12] The lubricating oil composition according to any one of [1] to [11], wherein the lubricating oil composition is free of poly(meth)acrylate as a viscosity index improver.

[13] The lubricating oil composition according to any one of [1] to [12], wherein the content of nitrogen component is 1000 ppm by mass or more on a total amount basis of the composition.

[14] The lubricating oil composition according to any one of [1] to [13] for use in both gasoline and diesel engines.

[15] The lubricating oil composition of any one of [1] to [13] for use in a diesel engine.

[Effect of the Invention]

[0010] The lubricating oil composition according to the present invention can have a good balance of caulking resistance, LSPI suppressing performance, and high-temperature cleaning properties. Such a lubricating oil composition can be suitably used for a supercharged engine which requires a high degree of caulking resistance.

[Mode for Carrying out the Invention]

[Lubricating Oil Composition]

[0011] A lubricating oil composition according to the present invention comprises at least (A) a lubricating oil base oil, (B) a calcium-based cleaning agent, (C) a magnesium-based cleaning agent, (D) a viscosity index improver, and (E) a nitrogen-containing dispersing agent, and may further comprise (F) an ashless friction modifier, (G) a molybdenum-containing compound, and (H) an anti-wear agent. The lubricating oil composition according to the present invention can be suitably used for an internal combustion engine, particularly a supercharged engine. In addition, the lubricating oil composition according to the present invention can be used for both gasoline and diesel engines, or can be used for a diesel engine. Each of the ingredients constituting the lubricating oil base oil according to the present invention shall be described in details below.

[(A) Lubricating oil base oil]

[0012] A lubricating oil base oil is not particularly limited, and examples thereof include paraffin base oil, normal paraffin base oil, isoparaffin base oil, and mixtures thereof, which are obtained by atmospheric distillation and/or vacuum distillation of crude oil, thereby giving a lubricant fraction which is then purified by one or a combination of two or more selected from purification treatments such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrorefining, sulfuric acid washing, clay treatment, and the like.

[0013] Preferable examples of the lubricating oil base oil include base oils obtained by using the following base oils (1) to (8) as raw materials, purifying those raw material oils and/or the lubricating oil fraction recovered from those raw material oils with a predetermined purification method, and recovering the lubricating oil fraction.

(1) Distillate oil obtained by atmospheric distillation of paraffin-based crude oil and/or mixed-based crude oil;
(2) Distillate oil obtained by reduced-pressure distillation of paraffin-based crude oil and/or mixed-based crude oil (WVGO);
(3) Wax (slack wax, etc.) obtained by a lubricating oil dewaxing step and/or synthetic wax (Fischer-Tropsch wax, GTL wax, etc.) obtained by a gas to liquid (GTL) process;
(4) Mixed oil of one or two or more selected from base oils (1) to (3) and/or mild hydrocracking treated oil of the mixed oil;
(5) Mixed oil of two or more selected from base oils (1) to (4);
(6) Deasphalting oil (DAO) of base oils (1), (2), (3), (4) or (5);
(7) Mild hydrocracking treated oil (MHC) of base oil (6);
(8) Mixed oil of two or more selected from base oils (1) to (7).

Preferred as the above-mentioned predetermined purification method are hydropurification such as hydrocracking or hydrofinishing; solvent purification such as furfural solvent extraction; dewaxing such as solvent dewaxing or catalytic dewaxing; clay purification using acid clay or activated clay; and chemical (acid or alkali) cleaning such as sulfuric acid cleaning or caustic soda cleaning. In the present invention, one of these purification methods may be performed alone, or two or more of these purification methods may be performed in combination. When two or more purification methods are combined, the order can be selected as needed with no particular limitation.

Further, the following base oils (9) and (10) are particularly suitable as the lubricating oil base oil, which are obtained by performing a predetermined treatment for the base oil selected from the base oils (1) to (8) above or the lubricating oil fraction recovered from the base oils.

(9) A hydrocracking base oil obtained by hydrocracking the base oil selected from the base oils (1) to (8) above or the lubricating oil fraction recovered from the base oils, thereby obtaining a resultant and carrying out dewaxing treatment such as solvent dewaxing or catalytic dewaxing on the resultant or the lubricating oil fraction recovered from distillation, etc. from the resultant, or carrying out distillation after carrying out the dewaxing treatment.
(10) A hydroisomerized base oil obtained by hydroisomerizing a base oil selected from the base oils (1) to (8) or a lubricating oil fraction recovered from the base oils, and subjecting the resultant or the lubricating oil fraction recovered from the resultant by distillation, etc. to a dewaxing treatment such as solvent dewaxing or catalytic dewaxing, or carrying out distillation after the dewaxing treatment. Preferred is a base oil produced by undergoing the catalytic dewaxing step as the dewaxing step.

[0014] In obtaining the lubricating oil base oil of (9) or (10) above, a solvent purification treatment and/or a hydrofinishing treatment step may be further performed at an appropriate stage as necessary.

[0015] Although the catalyst used for the hydrocracking/hydroisomerization is not particularly limited, preferred for use is a hydrocracking catalyst in which a complex oxide having a decomposition activity (for example, silica alumina, alumina boria, silica zirconia, etc.) or a combination of one or more types of the complex oxide and bound with a binder is used as a carrier, and a metal having a hydrogenation ability (for example, one or more of metals of Group VIa and Group VIII of the Periodic Table) is supported, or a hydroisomerization catalyst in which a metal having a hydrogenation ability including at least one of metal of Group VIII is supported on a carrier containing a zeolite (for example, ZSM-5, zeolite beta, SAPO-11, etc.). The hydrocracking catalyst and the hydroisomerization catalyst may be used in combination such as by lamination or mixing.

[0016] The reaction conditions during the hydrocracking/hydroisomerization are not particularly limited, and it is preferable that the hydrogen partial pressure is 0.1 to 20 MPa, the average reaction temperature is 150 to 450 °C, LHSV is 0.1 to 3.0 hr^{-1}, and the hydrogen / oil ratio is 50 to 20000 scf/b.

[0017] The kinematic viscosity of the lubricating oil base oil at 100 °C is preferably 2.0mm^2/s or more, more preferably 2.5mm^2/s or more, further preferably 3.0mm^2/s or more, further more preferably 3.5mm^2/s or more, and preferably 8.0mm^2/s or less, more preferably 7.0mm^2/s or less, further preferably 6.0mm^2/s or less, further more preferably 5.0mm^2/s or less. When the kinematic viscosity of the lubricating oil base oil at 100 °C is within the above-described numerical ranges, sufficient fuel efficiency can be obtained, and the oil film can be formed satisfactorily at the lubrication point, resulting in excellent lubricity. As used herein, "kinematic viscosity at 100 °C" means kinematic viscosity at 100 °C measured according to ASTM D-445.

[0018] The kinematic viscosity of the lubricating oil base oil at 40 °C is preferably 6.0mm^2/s or more, more preferably 8.0mm^2/s or more, further preferably 10mm^2/s or more, further more preferably 15mm^2/s or more, and preferably 40mm^2/s or less, more preferably 30mm^2/s or less, further preferably 25mm^2/s or less, further more preferably 20mm^2/s or less. When the kinematic viscosity of the lubricating oil base oil at 40 °C is within the above-mentioned numerical ranges, sufficient fuel efficiency can be obtained, and the oil film can be formed satisfactorily at the lubrication point, resulting in excellent lubricity. As used herein, "kinematic viscosity at 40 °C" means kinematic viscosity at 40 °C measured according to ASTM D-445.

[0019] The viscosity index of the lubricating oil base oil is preferably 100 or more, more preferably 110 or more, and further more preferably 120 or more. When the viscosity index is within the above-mentioned numerical ranges, viscosity-temperature characteristics, heat/oxidation stability, and volatility prevention properties of the lubricating oil composition are improved, so that the friction coefficient is reduced and thus wear prevention properties can be improved. As used herein, "viscosity index" means a viscosity index measured in accordance with JIS K 2283-1993.

[0020] The density (p15) of the lubricating oil base oil at 15 °C is preferably 0.860 or less, more preferably 0.850 or less, and further preferably 0.840 or less. As used herein, the density at 15 °C means the density at 15 °C measured according to JIS K 2249-1995.

[0021] The pour point of the lubricating oil base oil is preferably -10 °C or less, more preferably -12.5 °C or less, and further preferably -15 °C or less. When the pour point is within the above numerical ranges, low-temperature fluidity of the entire lubricant composition can be improved. As used herein, "pour point" means a pour point measured in accordance with JIS K 2269-1987.

[0022] The sulfur component of the lubricating oil base oil depends on the sulfur component of the raw material. For example, when a substantially sulfur-free raw material such as a synthetic wax component obtained by a Fischer-Tropsch reaction, etc. is used, a substantially sulfur-free lubricating oil base oil can be obtained. When a raw material including sulfur such as a slack wax obtained by a refining process of the lubricating oil base oil or a microwax component obtained by a refining process of the lubricating oil base oil is used, the sulfur component in the lubricating oil base oil is usually 100 ppm by mass or more. In the lubricating oil base oil, the sulfur component is preferably 100 ppm by mass or less, more preferably 50 ppm by mass or less, and further preferably 10 ppm by mass or less from the viewpoint of improvement of heat / oxidation stability and sulfur reduction. As used herein, "sulfur component" means a pour point measured in accordance with JIS K 2541-2003.

[0023] The % C_P of the lubricating oil base oil is preferably 70 or more, more preferably 75 or more, further preferably 80 or more. When the % C_P of the lubricating oil base oil is within the above numerical ranges, viscosity-temperature characteristics, heat/oxidation stability, and friction characteristics are improved, and also solubility of the additive is improved.

[0024] The % C_N of the lubricating oil base oil is preferably 30 or less, more preferably 25 or less, further preferably 20 or less, particularly preferably 15 or less. In addition, the % C_N of the lubricating oil base oil is preferably 1 or more and more preferably 4 or more. When the % C_N of the lubricating oil base oil is within the above-mentioned ranges, viscosity-temperature characteristics,thermal/oxidation stability, and friction characteristics are improved, and also solubility of the additive is improved.

[0025] The % C_A of the lubricating oil base oil is preferably 2 or less, more preferably 1 or less, further preferably 0.8 or less, and particularly preferably 0.5 or less. When the % C_A of the lubricating oil base oil is within the above-described numerical range, viscosity-temperature characteristics, heat/oxidation stability, and fuel efficiency are improved.

[0026] As used herein, % C_P,% C_N, and % C_A refer to the percentage of the total number of paraffin carbon atoms, the percentage of the total number of naphthenic carbon atoms, and the percentage of the total number of aromatic carbon atoms, respectively, as calculated from a method according to ASTM D 3238 - 85 (n-d-M ring analysis). That is, the preferred ranges for % C_P,% C_N, and % C_A as above are based on the values determined by the above method, and the % C_N calculated from the above method may be greater than 0, even for example for a lubricating oil base oil free of a naphthenic content.

[0027] The content of the saturated component in the lubricating oil base oil is preferably 90% by mass or more, preferably 95% by mass or more, and more preferably 99% by mass or more, on a total amount basis of the lubricating oil base oil. The proportion of the cyclic saturated component in the saturated component is preferably 40% by mass or less, preferably 35% by mass or less, preferably 30% by mass or less, more preferably 25% by mass or less, and further preferably 21% by mass or less. Further, the proportion of the cyclic saturated component in the saturated component is preferably 5% by mass or more and more preferably 10% by mass or more. Owing to the fact that the content of the saturated component and the proportion of the cyclic saturated component in the saturated component each satisfying the above conditions, the viscosity-temperature characteristics and heat/oxidation stability can be improved, and when an additive is added to the lubricating oil base oil, the function of the additive can be expressed at a higher level while sufficiently and stably dissolving and retaining the additive in the lubricating oil base oil. Further, it is possible to improve friction characteristics of the lubricating oil base oil itself, and as a result, it is possible to improve the friction reduction effect, leading to improvement in fuel efficiency. As used herein, the saturated component means a value measured in accordance with ASTM D 2007-93.

[0028] A similar method capable of obtaining a similar result can be used in the separation method of the saturated component, or the composition analysis of the cyclic saturated component, the acyclic saturated component, or the like. In addition to the method described in ASTM D 2007-93 above, examples include a method described in ASTM D 2425-93, a method described in ASTM D 2549-91, a method by high-performance liquid chromatography (HPLC), or modified methods of these methods.

[0029] The aromatic component in the lubricating oil base oil is preferably 10% by mass or less, more preferably 5% by mass or less, further preferably 4% by mass or less, further more preferably 3% by mass or less, and most preferably 2% by mass or less, and may be 0% by mass on a total amount basis of the lubricating oil base oil. When the content of the aromatic component is within the above-described numerical ranges, viscosity-temperature characteristics, thermal/oxidation stability and friction characteristics, as well as anti-volatilization properties and low-temperature viscosity characteristics are improved.

[0030] In the present specification, the aromatic component means a value measured according to ASTM D 2007-93. Examples of the aromatic component include alkylbenzene, alkylnaphthalene, anthracene, phenanthrene, and their alkylated products, compounds having four or more fused benzene rings, and aromatic compounds having heteroatoms such as pyridines, quinolines, phenols and naphthols.

[0031] As the lubricating oil base oil, group II base oil, group III base oil, group IV base oil, or group V base oil of the API base oil classification, or a mixture of these base oils can be preferably used. The API group II base oil is a mineral oil base oil having a sulfur component of 0.03% by mass or less, a saturation content of 90% by mass or more, and a viscosity index of 80 or more and less than 120. The API group III base oil is a mineral oil base oil having a sulfur component of 0.03% by mass or less, a saturation content of 90% by mass or more, and a viscosity index of 120 or more. The API group IV base oil is a poly α-olefin base oil. The API group V base oil is an ester base oil.

[0032] A synthetic base oil may be used as the lubricating oil base oil. Examples of the synthetic base oil include poly α-olefin and hydrides thereof, isobutene oligomer and hydrides thereof, isoparaffin, alkylbenzene, alkylnaphthalene, diester (ditridecyl glutalate, di-2-ethylhexyl adipate, diisodecyl adipate, ditridecyl adipate, di-2-ethylhexyl sebacate, etc.), polyol ester (trimethylol propane caprylate, trimethylol propane pelargonate, pentaerythritol 2-ethylhexanoate, pentaerythritol pelargonate, etc.), polyoxyalkylene glycol, dialkyldiphenyl ether, polyphenyl ether, and mixtures thereof, among which poly α-olefin is preferable. Typical examples of poly α-olefin include oligomers or co-oligomers of α-olefins having 2 to 32 carbon atoms, preferably 6 to 16 carbon atoms (1-octene oligomer, decene oligomer, ethylene-propylene co-oligomer, etc.), and hydrogenation products thereof.

[0033] The process for producing the poly α-olefin is not particularly limited, but may include, for example, a process for polymerizing the α-olefin in the presence of a polymerization catalyst such as a catalyst comprising a complex of aluminum trichloride or boron trifluoride with water, alcohol (ethanol, propanol, butanol, etc.), carboxylic acid or ester.

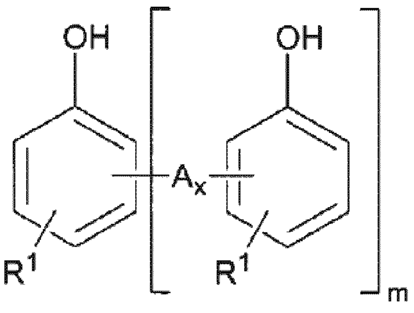
[0034] The lubricating oil base oil may comprise a single base oil component or may comprise multiple base oil components as a whole lubricating oil base oil.

[0035] When the lubricating oil composition is a multi grade oil, the content of the lubricating base oil in the lubricating oil composition is usually 70 mass% or more, preferably 75 mass% or more, more preferably 80 mass% or more, and usually 90 mass% or less, on a total amount basis of the lubricating oil composition. When the lubricating oil composition is a single grade oil, the content of the lubricating base oil in the lubricating oil composition is usually 80 mass% or more, preferably 85 mass% or more, more preferably 90 mass% or more, and usually 95 mass% or less, on a total amount basis of the lubricating oil composition.

[(B) Calcium-based Cleaning Agent]

[0036] Examples of the calcium-based cleaning agent include a phenate-based cleaning agent, a sulfonate-based cleaning agent, and a salicylate-based cleaning agent. These cleaning agents can be used alone or two or more is possible in combination.

[0037] Preferred examples of the phenate cleaning agent include overbased salts of calcium salts of compounds having a structure represented by the following formula (1).



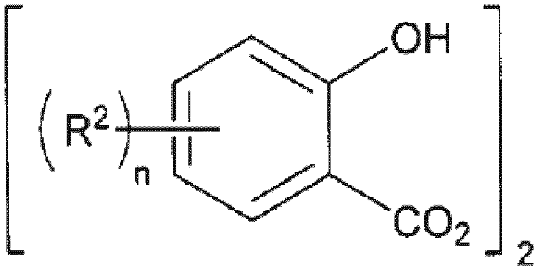
(1)

[0038] In formula (1), R^1 represents a linear or branched chain having 6 to 21 carbon atoms, a saturated or unsaturated alkyl group or alkenyl group, m represents the degree of polymerization and represents an integer of 1 to 10, A represents a sulfide (-S-) group or a methylene ($-CH_2-$) group, and x represents an integer of 1 to 3. In addition, R^1 may be a combination of two or more different groups. The number of carbon atoms in R^1 in formula (1) is preferably 9 to 18, and more preferably 9 to 15. When the number of carbon atoms in R^1 is within the above-mentioned range, solubility and heat resistance are improved. The polymerization degree m in Formula (1) is preferably 1 to 4. Heat resistance can be improved when the polymerization degree m is in this range.

[0039] Preferred examples of a sulfonate-based cleaning agent include calcium salts of an alkyl aromatic sulfonic acid obtained by sulfonating an alkyl aromatic compound or basic salts or overbased salts thereof. The weight average molecular weight of the alkyl aromatic compound is preferably 400 to 1500 and more preferably 700 to 1300.

[0040] Examples of alkyl aromatic sulfonic acids include the so-called petroleum sulfonic acids and synthetic sulfonic acids. Examples of petroleum sulfonic acids include those obtained by sulfonating an alkyl aromatic compound of a lubricating oil fraction of a mineral oil and the so-called mahogany acids produced as a by-product in the production of white oil, and the like. One example also includes those obtained by sulfonating alkylbenzene having a linear or branched alkyl group obtained by recovering by-products in a production plant of alkylbenzene which is the raw material of a detergent, or by alkylating benzene with polyolefin. Another example of synthetic sulfonic acid includes one which is obtained by sulfonating alkyl naphthalene such as dinonyl naphthtalene. Also, there is no particular limitation to the sulfonating agent to sulfonate these alkyl aromatic compounds, examples thereof including oleum and anhydrous sulfuric acid.

[0041] Examples of the salicylate-based cleaning agent preferably include calcium salicylate or basic salts or overbased salts thereof. Preferred example of the calcium salicylate includes a compound represented by the following formula (2).



(2)

[0042] In formula (2) above, R^2 each independently represent an alkyl group or an alkenyl group having 14 to 30 carbon atoms, and M represents calcium. N represents 1 or 2, preferably 1, and may be a mixture of a compound of n=1 and a compound of n=2. When n=2, R^2 may be a combination of different groups. A preferred embodiment of the salicylate-based cleaning agent includes calcium salicylate having n=1 in the above general formula (2) or basic salts or overbased salts thereof.

[0043] The method for producing calcium salicylate is not particularly limited, and known methods for producing monoalkyl salicylate can be used. For example, the calcium salicylate can be obtained by reacting a monoalkyl salicylic acid obtained by alkylation of the starting material, phenol with an olefin and then carboxylation with carbon dioxide, etc., or a monoalkyl salicylic acid obtained by alkylation of the raw material, salicylic acid with an equivalent amount of the above olefin with a calcium base such as an oxide or hydroxide of calcium, or by converting these monoalkyl salicylic acids into an alkali metal salt such as a sodium salt or potassium salt and then exchanging the alkali metal salt with a calcium salt or the like, and thereby obtaining a calcium salicylate.

[0044] The calcium-based cleaning agent may be overbased with carbonate (calcium carbonate) or with borate (calcium borate).

[0045] A method for obtaining a calcium-based cleaning agent overbased with calcium carbonate is not particularly limited, and can be obtained, for example, by reacting a neutral salt of a calcium-based cleaning agent (calcium phenate, calcium sulfonate, calcium salicylate, etc.) with a calcium base (calcium hydroxide, oxide, etc.) in the presence of carbon dioxide gas.

[0046] A method for obtaining a calcium cleaning agent overbased with calcium borate is not particularly limited, and can be obtained by reacting a neutral salt of a calcium cleaning agent (calcium phenate, calcium sulfonate, calcium salicylate, etc.) with a calcium base (calcium hydroxide, oxide, etc.) in the presence of boric acid or boric anhydride or borate.

[0047] As the calcium-based cleaning agent, calcium phenate, calcium sulfonate, calcium salicylate, or a combination thereof can be used, and it is preferable to use calcium salicylate.

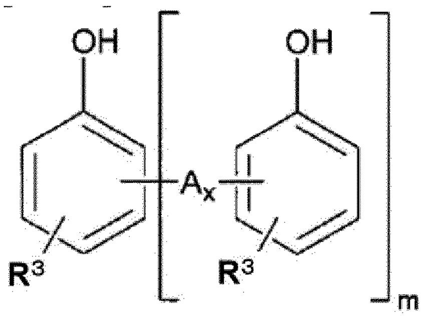
[0048] The total base number of the calcium-based cleaning agent is not particularly limited, and is preferably 20 mgKOH/g or more, more preferably 50 mgKOH/g or more, further preferably 100 mgKOH/g or more, and preferably 500 mgKOH/g or less, more preferably 400 mgKOH/g or less, and further preferably 350 mgKOH/g or less. When the total base number of the calcium-based cleaning agent is within the above-mentioned numerical value ranges, it is possible to maintain the acid neutralizing properties required for the lubricating oil and further improve high-temperature cleaning properties. Note that, when two or more calcium-based cleaning agents are mixed and used, it is preferable that the base number obtained by mixing be within the above-mentioned ranges. The total base number is a value measured by ASTM D2896.

[0049] The content of the calcium-based cleaning agent in the lubricating oil composition is 1100 mass ppm or more to 1900 mass ppm or less, preferably 1150 mass ppm or more, more preferably 1200 mass ppm or more, preferably 1850 mass ppm or less, and more preferably 1800 mass ppm or less as a calcium amount, on a total amount basis of the lubricating oil composition. When the content of the calcium-based cleaning agent is within the above-mentioned numerical value ranges, it is possible to improve high-temperature cleaning properties while maintaining caulking resistance and the LSPI suppressing performance.

[(C) Magnesium-based Cleaning Agent]

[0050] Examples of the magnesium-based cleaning agent include a phenate-based cleaning agent, a sulfonate-based cleaning agent, and a salicylate-based cleaning agent. These cleaning agents may be used alone or two or more is also possible in combination.

[0051] Preferred examples as the phenate-based cleaning agent can include overbased salts of magnesium salts of compounds having a structure represented by the following formula (3).



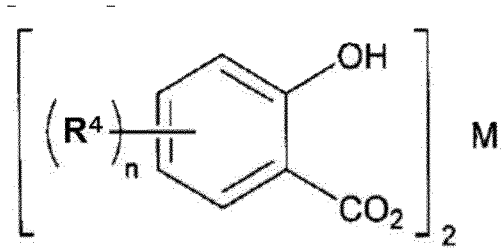
(3)

[0052] In formula (3), R^3 represents a linear or branched chain having 6 to 21 carbon atoms, a saturated or unsaturated alkyl group or alkenyl group, m represents the degree of polymerization and represents an integer of 1 to 10, A represents a sulfide (-S-) group or a methylene (-CH_2-) group, and x represents an integer of 1 to 3. Note that, R^3 may be a combination of two or more different groups. The carbon number of R^3 in formula (3) is preferably 9 to 18, and more preferably 9 to 15. When the carbon number of R^3 is in the above-mentioned ranges, solubility and heat resistance improve. The polymerization degree m in formula (3) is preferably 1 to 4. When the polymerization degree m is within the range, heat resistance improves.

[0053] Preferred examples of the sulfonate-based cleaning agent can include a magnesium salt of an alkyl aromatic sulfonic acid obtained by sulfonating an alkyl aromatic compound or basic salts or overbased salts thereof. The weight average molecular weight of the alkyl aromatic compound is preferably 400 to 1500, and more preferably 700 to 1300.

[0054] Examples of alkyl aromatic sulfonic acids include the so-called petroleum sulfonic acids and synthetic sulfonic acids. Examples of petroleum sulfonic acids include those obtained by sulfonating an alkyl aromatic compound of a lubricating oil fraction of a mineral oil and the so-called mahogany acid produced as a by-product in the production of white oil, and the like. One example of the synthetic sulfonic acids includes those obtained by sulfonating alkylbenzenes having linear or branched alkyl groups, obtainable by recovering by-products in a manufacturing plant of the raw material of a detergent, alkylbenzene or by alkylating polyolefin of benzene. Another example of the synthetic sulfonic acids includes those obtained by sulfonating alkyl naphthalene such as dinonyl naphthalene. Also, there is no limitation for the sulfonating agent to sulfonate these alkyl aromatic compounds, and for example, oleum or sulfuric acid anhydride can be used.

[0055] Examples of the salicylate-based cleaning agent can include magnesium salicylate or basic salts or overbasic salts thereof. Examples of the magnesium salicylate can preferably include the compounds represented by the following formula (4).



(4)

[0056] In formula (4), R^4 each independently represents an alkyl group or an alkenyl group having 14 to 30 carbon atoms, and M represents magnesium. N represents 1 or 2 and is preferably 1, but may be a mixture of a compound of n = 1 and a compound of n = 2. When n=2, R^4 may be a combination of different groups. A preferred embodiment of the salicylate-based cleaning agent includes magnesium salicylate wherein n = 1 in the general formula (4), or basic salts or overbasic salts thereof.

[0057] The method for producing magnesium salicylate is not particularly limited, and known methods for producing monoalkyl salicylate and the like can be used. For example, a magnesium salicylate can be obtained by using phenol as a starting raw material and olefin to conduct alkylation, conducting carboxylation with carbon dioxide, etc. to obtain monoalkyl salicylic acid or a salicylic acid which are then used as starting raw materials, and then reacting a base of magnesium such as an oxide or a hydroxide of magnesium with monoalkyl salicylic acid which is obtained by alkylation using an equivalent amount of the above-described olefin, or by making these monoalkyl salicylic acid, etc. once into an alkali metal salt such as sodium salt or potassium salt and then metal interchanging with magnesium salt, or the like.

[0058] The magnesium-based cleaning agent may be overbased with a carbonate (magnesium carbonate) or with a borate (magnesium borate).

[0059] A method for obtaining a magnesium-based cleaning agent overbased with a carbonate of magnesium is not particularly limited, and can be obtained, for example, by reacting a neutral salt of a magnesium-based cleaning agent (magnesium phenate, magnesium sulfonate, magnesium salicylate, etc.) with a base of magnesium (hydroxide, oxide, etc., of magnesium) in the presence of carbon dioxide gas.

[0060] A method for obtaining a magnesium-based cleaning agent overbased with a borate of magnesium is not particularly limited, and can be obtained by reacting a neutral salt of a magnesium-based cleaning agent (magnesium phenate, magnesium sulfonate, magnesium salicylate, etc.) with a base of magnesium (hydroxide, oxide, etc., of magnesium) in the presence of boric acid or boric anhydride or borate.

[0061] As the magnesium-based cleaning agent, used can be made to magnesium phenate, magnesium sulfonate, magnesium salicylate, or a combination thereof, and preferably magnesium salicylate is used.

[0062] The total base number of the magnesium-based cleaning agent is not particularly limited, and is preferably 20 mgKOH/g or more, more preferably 50 mgKOH/g or more, further preferably 100 mgKOH/g or more, and preferably 500 mgKOH/g or less, more preferably 400 mgKOH/g or less. When the total base number of the magnesium-based cleaning agent is within the above-mentioned ranges, acid-neutralizing properties required for the lubricating oil can be maintained, and high-temperature cleaning properties can be improved further. When two or more magnesium-based cleaning agents are mixed and used, it is preferable that the base number obtained by mixing be within the above-mentioned ranges. Note that, the total base number is a value measured by ASTM D2896.

[0063] The content of the magnesium-based cleaning agent in the lubricating oil composition is preferably 100 ppm by mass or more, more preferably 200 ppm by mass or more, further preferably 300 ppm by mass or more, and preferably 1000 ppm by mass or less, more preferably 900 ppm by mass or less, further preferably 800 ppm by mass or less, on a total amount basis of the lubricating oil composition. When the content of the magnesium-based cleaning agent is within the above numerical ranges, high-temperature cleaning properties can be further improved while caulking resistance and the LSPI suppression performance are maintained.

[(D) Viscosity Index Improver]

[0064] Examples of the viscosity index improver include a styrene-diene copolymer and an ethylene-α-olefin copolymer, and preferably, use is made to a styrene-diene copolymer. These viscosity index improvers can be used alone or two or more is possible in combination. By using these viscosity index improvers, caulking resistance can be improved while maintaining the LSPI suppression performance and high-temperature cleaning properties.
[0065] The styrene-diene copolymer comprises one or two or more styrenic monomers selected from styrene and its hydrides and one or two or more diene monomers selected from diene and its hydrides, as monomer units. Examples of the diene include, for example, butadiene and isoprene.
[0066] The content of styrenic monomer units in the styrene-diene copolymer may be, for example, 1-30 mol% or 5-20 mol% on a total amount basis of the monomer units. The content of diene-based monomer units in the styrene-diene copolymer may be, for example, 70-99 mol% or 80-95 mol% on a total amount basis of the monomer units.
[0067] The ethylene-α-olefin copolymer comprises ethylene and an α-olefin having three or more carbon atoms as monomer units. Examples of the α-olefin having three or more carbon atoms include propylene, 1-butene, 1-pentene, 3-methyl-1-butene, 1-hexene, 4-methyl-1-pentene, 3-methyl-1-pentene, 1-octene, and 1-decene, with propylene being preferred.
[0068] The content of ethylene units in the ethylene-α-olefin copolymer may be, for example, 30-80 mol%, 35-75 mol%, or 40-70 mol% on a total amount basis of the monomer units. The content of α-olefin units in the ethylene-α-olefin copolymer may be, for example, 20-70 mol%, 25-65 mol%, or 30-60 mol% on a total amount basis of the monomer units.
[0069] The lubricating oil composition preferably does not include poly(meth)acrylate as a viscosity index improver. The lubricating oil composition without poly(meth)acrylate makes it possible to further improve the caulking resistance.
[0070] The viscosity index improver has PSSI (a permanent shear stability index) in accordance with the diesel injector method of preferably 40 or less, more preferably 35 or less, further preferably 30 or less, and usually greater than 0. When the PSSI is within the above-described numerical ranges, shear stability is maintained, fuel efficiency is improved, and the kinematic viscosity and HTHS viscosity after use can be maintained at a certain level or higher. As used herein, "PSSI" refers to a permanent shear stability index of a polymer calculated in accordance with ASTM D 6022-01 (Standard Practice for Calculation of Permanent Shear Stability Index) and based on data measured by ASTM D 6278-02 (Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus).
[0071] The viscosity index improver has a weight average molecular weight (Mw) of, for example, preferably 10,000 or more, more preferably 50,000 or more, further preferably 100,000 or more, further more preferably 200,000 or more, and preferably 1,000,000 or less, more preferably 700,000 or less, and further preferably 500,000 or less. When the weight average molecular weight of the viscosity index improver is within the above-described numerical ranges, a sufficient viscosity index improving effect is obtained, fuel efficiency is excellent, and appropriate viscosity increasing effect, shear stability, solubility in lubricating oil base oil, and storage stability become excellent.
[0072] The content of the viscosity index improver is preferably 0.1% by mass or more, more preferably 0.5% by mass or more, further preferably 1.0% by mass or more, and preferably 20.0% by mass or less, more preferably 15.0% by mass or less, and further preferably 10.0% by mass or less, on a total amount basis of the lubricating oil composition. When the content of the viscosity index improver is within the above-described numerical ranges, the caulking resistance can be further improved while the viscosity-temperature characteristics are excellent.

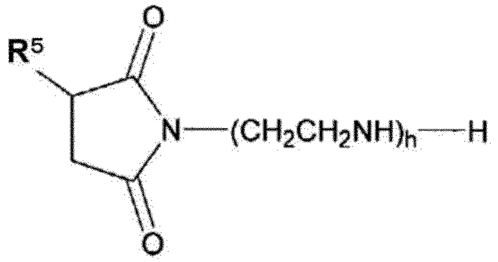
[(E) Nitrogen-Containing Dispersing Agent]

[0073] A nitrogen-containing dispersing agent (hereinafter sometimes referred to as "Component (E)") is not particularly limited, and for example, one or more compounds selected from the following compounds (E-1) to (E-3) can be used.

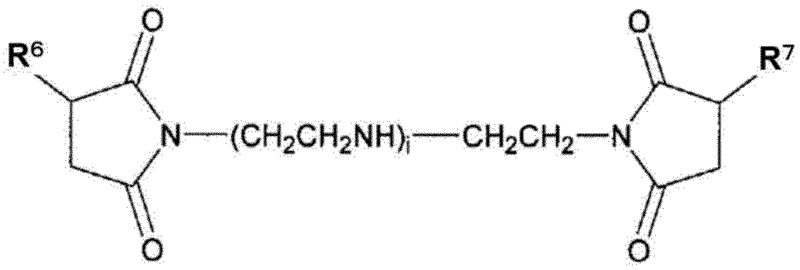
(E-1) Succinimide having at least one alkyl or alkenyl group in the molecule or a derivative thereof (hereinafter referred to as "Component (E-1)");
(E-2) Benzylamine having at least one alkyl or alkenyl group in the molecule or a derivative thereof (hereinafter referred to as "Component (E-2)"); and
(E-3) Polyamine having at least one alkyl or alkenyl group in the molecule or a derivative thereof (hereinafter, referred to as "Component (E-3)").

[0074] Component (E-1) can be particularly preferably used as Component (E).
[0075] Examples of the succinimide having at least one alkyl group or alkenyl group in the molecule among the

components (E-1) include compounds represented by the following formulae (5) or (6).



(5)



(6)

[0076] In formula (5), R^5 represents an alkyl or alkenyl group having 40 to 400 carbon atoms, and h represents an integer of 1 to 5, preferably 2 to 4. R^5 preferably has 60 or more carbon atoms and preferably 350 or less.

[0077] In formula (6), R^6 and R^7 each independently represent an alkyl group or an alkenyl group having 40 to 400 carbon atoms, and may be a combination of different groups. R^6 and R^7 are particularly preferably a polybutenyl group. i indicates an integer from 0 to 4 and preferably 1 to 3. The number of carbon atoms of R^6 and R^7 is preferably 60 or more and preferably 350 or less.

[0078] When the number of carbon atoms of R^5 to R^7 in formulae (5) and (6) is equal to or greater than the lower limit, good solubility in the lubricating oil base oil can be obtained. On the other hand, when the number of carbon atoms of R^5 to R^7 is equal to or less than the upper limit, the low-temperature fluidity of the lubricant composition can be improved.

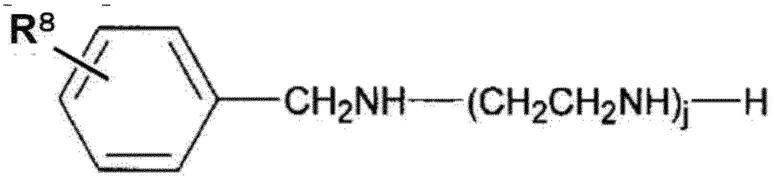
[0079] The alkyl or alkenyl group (R^5 to R^7) in formulae (5) and (6) may be linear or branched, and preferably includes branched alkyl or alkenyl groups derived, for example, from oligomers of olefins such as propylene, 1-butene, isobutene, or cooligomers of ethylene and propylene. Among these, branched alkyl or alkenyl groups derived from oligomers of isobutene, commonly referred to as polyisobutylene, or polybutenyl groups are most preferred.

[0080] The number average molecular weight of the alkyl or alkenyl group (R^5 to R^7) in Formula (5) and Formula (6) is preferably 800 to 3500.

[0081] Succinimide having at least one alkyl or alkenyl group in the molecule includes the so-called monotype succinimide represented by formula (5) wherein succinic anhydride is added to only one end of a polyamine chain, and the so-called bistype succinimide represented by formula (6) wherein succinic anhydride is added to both ends of a polyamine chain. The lubricating oil composition of the present invention may include either mono-type succinimide or bis-type succinimide, and also both may be included as a mixture.

[0082] A method for producing a succinimide having at least one alkyl group or alkenyl group in a molecule is not particularly limited, and for example, an alkyl succinic acid or an alkenyl succinic acid obtained by reacting a compound having an alkyl group or an alkenyl group having 40 to 400 carbon atoms with maleic anhydride at 100 to 200 °C can be obtained by reacting with a polyamine. Examples of the polyamine include diethylenetriamine, triethylenetetramine, tetraethylenepentamine, and pentaethylenehexamine.

[0083] As the benzylamine having at least one alkyl group or alkenyl group in the molecule among Component (E-2), a compound represented by the following formula (7) can be exemplified.



(7)

[0084] In Formula (7), R^8 represents an alkyl or alkenyl group having 40 to 400 carbon atoms, and j represents an integer of 1 to 5, preferably 2 to 4. R^8 preferably has 60 or more carbon atoms and preferably 350 or less.

[0085] The manufacturing method of Component (E-2) is not particularly limited. For example, there is a method in which a polyolefin such as a propylene oligomer, polybutene, or an ethylene-α-olefin copolymer is reacted with phenol to produce an alkyl phenol, and then formaldehyde is reacted with a polyamine such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, or pentaethylenehexamine by a Mannich reaction.

[0086] As the polyamine having at least one alkyl group or alkenyl group in the molecule among Component (E-3), a compound represented by the following formula (8) can be exemplified.

$$R^9\text{-NH-}(CH_2CH_2NH)_k\text{-H} \qquad (8)$$

[0087] In formula (8), R^9 represents an alkyl group or alkenyl group having 40 to 400 carbon atoms or less, and k represents an integer of 1 to 5, preferably 2 to 4. R^9 preferably has 60 or more carbon atoms and preferably 350 or less.

[0088] The manufacturing method of the component (E-3) is not particularly limited. For example, there is a method in which a polyolefin such as a propylene oligomer, polybutene, or an ethylene-α-olefin copolymer is chlorinated and then ammonia or a polyamine such as ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, or pentaethylenehexamine is reacted with the chlorinated polyolefin.

[0089] Examples of the derivatives of Components (E-1) to (E-3) include, for example, (i) modified compounds by oxygen-containing organic compound in which a part or whole of the residual amino groups and/or imino groups are neutralized or amidified by acting monocarboxylic acid having 1 to 30 carbon atoms such as fatty acid, polycarboxylic acid having 2 to 30 carbon atoms (for example, oxalic acid, phthalic acid, trimellitic acid, pyromellitic acid, etc.), anhydrides thereof or ester compounds, alkylene oxide having 2 to 6 carbon atoms, or hydroxyl(poly)oxyalkylene carbonate to succinimide, benzylamine or polyamine having at least one alkyl group or alkenyl group as above in the molecule (hereinafter referred to as "the above-mentioned nitrogen-containing compound"); and (ii) boric acid modified compounds in which a part or whole of the residual amino groups and/or imino groups are neutralized or amidified by acting boric acid to the above-mentioned nitrogen-containing compounds; (iii) phosphoric acid modified compounds in which a part or whole of the residual amino groups and/or imino groups are neutralized or amidified by acting phosphoric acid to the above-mentioned nitrogen-containing compounds; (iv) sulfuric acid modified compounds obtained by acting sulfuric acid to the above-mentioned nitrogen-containing compounds; and (v) modified compounds obtained by combining and carrying out two or more modifications selected from modification by an oxygen-containing organic compound with the above-mentioned nitrogen containing compound, boron modification, phosphoric acid modification, sulfur modification.

[0090] The molecular weight of Component (E) is not particularly limited, and the weight average molecular weight of Component (E-1) is preferably 1,000 to 20,000, and more preferably 2,000 to 10,000.

[0091] The content of Component (E) is preferably 0.1% by mass or more, more preferably 0.5% by mass or more, further preferably 1.0% by mass or more, and preferably 10% by mass or less, more preferably 7% by mass or less, and further preferably 5% by mass or less, on a total amount basis of the lubricating oil composition. When the content of Component (E) is not less than the above-mentioned lower limit value, the caulking resistance of the lubricating oil composition can be sufficiently improved. When the content of Component (E) is not more than the above-mentioned upper limit value, the fuel efficiency can be improved.

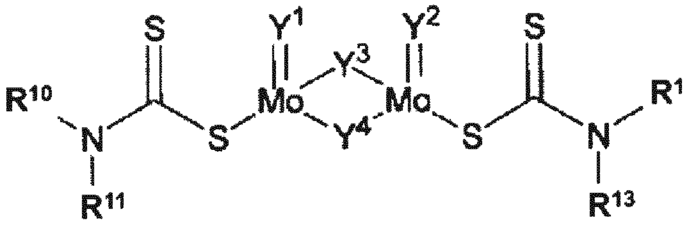
[(F) Ashless Friction Modifier]

[0092] The ashless friction modifier is not particularly limited, and a compound commonly used as a friction modifier for lubricating oils can be used. Examples of the ashless friction modifier include a compound having 6 to 50 carbon atoms and containing one or more hetero elements selected from an oxygen atom, a nitrogen atom and a sulfur atom in a molecule. More specifically, examples of the ashless friction modifier include an amine compound, a fatty acid ester, a fatty acid amide, a fatty acid, an aliphatic alcohol, an aliphatic ether, a urea compound and a hydrazide compound having at least one of an alkyl or alkenyl group of 6 to 30 carbon atoms, particularly a linear alkyl group, linear alkenyl group, branched alkyl group or branched alkenyl group of 6 to 30 carbon atoms in a molecule.

[0093] The content of the ashless friction modifier is preferably 0.01% by mass or more, more preferably 0.1% by mass or more, further more preferably 0.2% by mass or more, and preferably 2% by mass or less, more preferably 1% by mass or less, and furthermore preferably 0.8% by mass or less, on a total amount basis of the lubricating oil composition. When the content of the ashless friction modifier is within the above-described numerical ranges, the effect of friction reduction is improved, and also the effect of the anti-wear agent, etc. is not inhibited, and solubility of the additive can be maintained.

[(G) Molybdenum-containing Compound]

[0094] As for a molybdenum-containing compound (hereinafter referred to as "Component (G)") use can be made to, for example, (G1) molybdenum dithiocarbamate (molybdenum sulfide dithiocarbamate or oxymolybdenum sulfide dithiocarbamate. Hereinunder the term may be referred to as "Component (G1)"). Specifically, compounds represented by the following formula (9) can be used as Component (G1).



(9)

[0095] In the above general formula (9), R^{10} to R^{13} may be the same as or different from each other and each represents an alkyl group having 2 to 24 carbon atoms or an (alkyl) aryl group having 6 to 24 carbon atoms, preferably an alkyl group having 4 to 13 carbon atoms or an (alkyl) aryl group having 10 to 15 carbon atoms. The alkyl group may be any of a primary alkyl group, a secondary alkyl group and a tertiary alkyl group, and may be linear or branched. Note that, the "(alkyl)aryl" means an "aryl group or an alkylaryl group". In the alkylaryl group, the substitution position of the alkyl group in the aromatic ring is optional. Y^1 to Y^4 are each independently a sulfur atom or an oxygen atom, and at least one of Y^1 to Y^4 is a sulfur atom.

[0096] A Molybdenum-containing compound other than the (G1) component includes, for example, molybdenum-containing compounds containing sulfur such as a complex of molybdenum dithiophosphate; molybdenum compounds (for example, molybdenum oxides such as molybdenum dioxide and molybdenum trioxide, molybdenum acids such as orthomolybdenum acid, paramolybdenum acid, and (poly) molybdenum sulfide acid, metal salts and ammonium salts of these molybdenum acids, molybdenum sulfide such as molybdenum disulfide, molybdenum trisulfide, molybdenum pentasulfide, and polymolybdenum sulfide, molybdenum sulfide, metal salts or amine salts of molybdenum sulfide, molybdenum halides such as molybdenum chloride, and the like) with sulfur-containing organic compounds (e.g., alkyl(thio)xanthate, thiadiazole, mercaptothiadiazole, thiocarbonate, tetrahydrocarbyl thiuram disulfide, bis(di(thio)hydrocarbyl dithiophosphonates)disulfide, organic(poly)sulfide, sulfide esters, etc.) or other organic compounds; and a complex of sulfur-containing molybdenum compounds such as the above-described molybdenum sulfide and molybdenum sulfide acid with alkenyl succinimides. The molybdenum-containing compound may be a mononuclear molybdenum compound or a multinuclear molybdenum compound such as a binuclear molybdenum compound or a trinuclear molybdenum compound, etc.

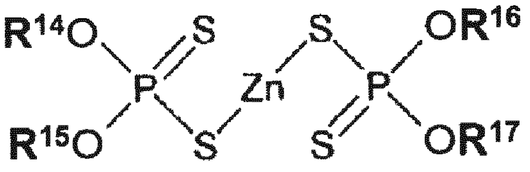
[0097] As the molybdenum-containing compound other than Component (G1), it is also possible to use a molybdenum-containing compound that does not contain sulfur as a constituent element. Specific examples of the molybdenum-containing compound that does not contain sulfur as a constituent element include a molybdenum-amine complex, a molybdenum-succinimide complex, a molybdenum salt of an organic acid, and a molybdenum salt of an alcohol, among which a molybdenum-amine complex, a molybdenum salt of an organic acid, and a molybdenum salt of an alcohol are preferred.

[0098] The content of Component (G) is preferably 10 mass ppm or more, preferably 100 mass ppm or more, and preferably 2000 mass ppm or less, more preferably 1000 mass ppm or less, and further preferably 500 mass ppm or less, as the molybdenum content on a total amount basis of molybdenum in the lubricating oil composition. When the content of Component (G) is within the above-mentioned numerical ranges, it is possible to improve the effect of friction reduction and further improve the LSPI suppressing performance.

[(H) Anti-wear Agent]

[0099] The anti-wear agent is not particularly limited, and compounds commonly used as the anti-wear agent for lubricating oils can be used. Examples of the anti-wear agent include sulfur-based, phosphorus-based, and sulfur-phosphorus-based anti-wear agents, and the like. Specifically, examples of the anti-wear agent include phosphorous esters, thiophosphorous esters, dithiophosphorous esters, trithiophosphorous esters, phosphoric esters, thiophosphoric esters, dithiophosphoric esters, trithiophosphoric esters, and amin salts, metal salts, and detivatives thereof, dithiocarbamates, zinc dithiocarbamates, disulfides, polysulfides, olefin sulfides, sulfurized fats and oils, etc.

[0100] Among these anti-wear agents, a phosphorus-based anti-wear agent is preferable, and particularly, zinc dialkyl dithiophosphate (ZnDTP) represented by the following formula (10) is preferable.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[0101] In formula (10), R^{14} to R^{17} each independently represent a linear or branched alkyl group having 1 to 24 carbon atoms, and may be a combination of different groups. The carbon number of R^{14} to R^{17} is preferably 3 or more, preferably 12 or less, and more preferably 8 or less. R^{14} to R^{17} may be any of a primary alkyl group, a secondary alkyl group, and a tertiary alkyl group, but preferred is a primary alkyl group, a secondary alkyl group, or a combination thereof, and further, the molar ratio of the primary alkyl group to the secondary alkyl group (primary alkyl group : secondary alkyl group) is preferably 0 : 100 to 30 : 70. This ratio may be a combination ratio of the alkyl chains in the molecule or a mixing ratio of ZnDTP having only a primary alkyl group and ZnDTP having only a secondary alkyl group. Owing to the fact that the secondary alkyl group is the main component, it is possible to improve the fuel efficiency.

[0102] The method for producing the zinc dialkyldithiophosphate is not particularly limited. For example, zinc dialkyldithiophosphate can be synthesized by reacting an alcohol having an alkyl group corresponding to R^{14} to R^{17} with diphosphorus pentasulfide to synthesize dithiophosphate, and neutralizing the dithiophosphate with zinc oxide.

[0103] The content of the anti-wear agent is preferably 0.1 mass% or more, more preferably 0.5 mass% or more, and preferably 5.0 mass% or less, more preferably 3.0 mass% or less, on a total amount basis of the lubricating oil composition. When the content of the anti-wear agent is within the above-described numerical ranges, a sufficient anti-wear effect can be obtained.

[(I) Antioxidant]

[0104] The antioxidant is not particularly limited, and compounds commonly used as an antioxidant for lubricating oils can be used. Examples of the antioxidant include an amine-based antioxidant and a phenol-based antioxidant, and preferred is an amine-based antioxidant. As for the amine-based antioxidant, known amide-based antioxidants can be used, including for example, alkylated diphenylamine, alkylated phenyl-α-naphthylamine, phenyl-α-naphthylamine, and phenyl-β-naphthylamine. As for the phenol-based antioxidants, known phenol-based antioxidants can be used, including for example, 2,6-di-tert-butyl-4-methylphenol (DBPC), 4,4'-methylenebis(2,6-di-tert-butylphenol), etc.

[0105] The content of the antioxidant is preferably 0.01% by mass or more, more preferably 0.1% by mass or more, and preferably 5% by mass or less, more preferably 3% by mass or less on a total amount basis of the lubricating oil composition. When the content of the antioxidant is within the above-described numerical ranges, a sufficient anti-oxidation effect can be obtained.

[Other Components]

[0106] The lubricating oil composition may further comprise other components than the above-described Components (A) to (I), such as rust-preventive agents, pour point depressants, demulsifiers, metal deactivators and antifoaming agents which are commonly used for the lubricating oil composition.

[0107] Rust inhibitors include, for example, petroleum sulfonate, alkylbenzene sulfonate, dinonylnaphthalene sulfonate, alkenyl succinic acid ester, polyhydric alcohol ester, and the like. The content of the rust inhibitor is preferably 0.01% by mass or more, more preferably 0.05% by mass or more, and preferably 10% by mass or less, more preferably 5% by mass or less, on a total amount basis of the lubricating oil composition.

[0108] As the pour point depressant, for example, use can be made to a polymethacrylate polymer that is compatible with the lubricating oil base oil. The content of the pour point depressant is preferably 0.01% by mass or more, more preferably 0.05% by mass or more, and preferably 10% by mass or less, more preferably 5% by mass or less, on a total amount basis of the lubricating oil composition.

[0109] Examples of the demulsifiers include polyalkylene glycol-based nonionic surfactants such as polyoxyethylene alkyl ether, polyoxyethylene alkyl phenyl ether, and polyoxyethylene alkyl naphthyl ether. The content of the demulsifiers is preferably 0.01% by mass or more, more preferably 0.05% by mass or more, and preferably 10% by mass or less, more preferably 5% by mass or less, on a total amount basis of the lubricating oil composition.

[0110] Examples of metal deactivators include imidazolines, pyrimidine derivatives, alkylthiadiazoles, mercaptobenzothiazoles, benzotriazoles or derivatives thereof, 1,3,4-thiadiazole polysulfides, 1,3,4-thiadiazolyl-2,5-bisdialkyldithiocarbamates, 2-(alkyldithio) benzimidazoles, β-(o-carboxybenzylthio)propionnitriles and the like. The content of the metal deactivator is preferably 0.01% by mass or more, more preferably 0.05% by mass or more, and preferably 10% by mass or less, more preferably 5% by mass or less, on a total amount basis of the lubricating oil composition.

[0111] Examples of the antifoaming agent include silicone oil having a kinematic viscosity at 25 °C of 1,000 to 100,000 mm^2 /s, alkenyl succinic acid derivatives, esters of polyhydroxy aliphatic alcohols and long-chain fatty acids, methyl salicylate, and o-hydroxybenzyl alcohol. The content of the antifoaming agent is preferably 0.01% by mass or more, more preferably 0.05% by mass or more and preferably 10% by mass or less, more preferably 5% by mass or less, on a total amount basis of the lubricating oil composition.

[Physical Properties of Lubricating Oil Composition]

[0112] The kinematic viscosity of the lubricating oil composition at 100 °C is preferably 4.0mm^2/s or more, more preferably 5.0mm^2/s or more, further preferably 5.5mm^2/s or more, further more preferably 6.1mm^2/s or more, and less than 12.5mm^2/s, more preferably less than 11.5mm^2/s, further preferably less than 10.0mm^2/s, further more preferably less than 9.3mm^2/s. When the kinematic viscosity at 100 °C of the lubricating oil composition is within the above-mentioned numerical ranges, the low-temperature viscosity characteristic improves, sufficient fuel efficiency is obtained, and the oil film is well formed at the lubrication portion, making the lubricity excellent.

[0113] The kinematic viscosity of the lubricating oil composition at 40 °C is preferably 20.0mm^2/s or higher, more preferably 25.0 s mm^2/s or higher, further preferably 30.0 mm^2/s or higher, further more preferably 35.0 mm^2/s or higher, and less than 80.0mm^2/ s, more preferably less than 70.0mm^2/s, further preferably less than 60.0mm^2/s, and further more preferably less than 55.0mm^2/s. When the kinematic viscosity at 40 °C of the lubricating oil composition is within the above numerical ranges, the low-temperature viscosity characteristic becomes excellent, sufficient fuel efficiency is obtained, and the oil film forms well at the lubrication portion, which makes the lubricity excellent.

[0114] The viscosity index of the lubricating oil composition is preferably equal to or greater than 120, more preferably equal to or greater than 130, further preferably equal to or greater than 140, and usually equal to or less than 300. When the viscosity index of the lubricating oil composition is within the above-mentioned numerical ranges, fuel efficiency can be improved while maintaining the HTHS viscosity at 150 °C.

[0115] The HTHS viscosity at 150 °C of a lubricating oil composition is preferably 1.7 mPa·s or more, more preferably 1.8 mPa·s or more, further preferably 1.9 mPa·s or more, further more preferably 2.0 mPa·s or more, and preferably 3.5 mPa·s or less, more preferably 3.2 mPa·s or less, further preferably 2.9 mPa·s or less, and further more preferably 2.6 mPa·s or less. When the HTHS viscosity of the lubricating oil composition at 150 °C is within the above-described numerical ranges, lubricity and fuel consumption performances improve. As used herein, the "HTHS viscosity at 150 °C" means high temperature high shear viscosity at 150 °C measured according to ASTM D-4683.

[0116] The content of the sulfur component in the lubricating oil composition is preferably 1.0 % by mass or less, more preferably 0.5 % by mass or less, further preferably 0.3 % by mass or less. When the content of the sulfur component in the lubricating oil composition is within the above-described ranges, it is possible to improve heat-oxidation stability.

[0117] The content of the nitrogen component in the lubricating oil composition is 700 mass ppm or more, preferably 800 mass ppm or more, more preferably 900 mass ppm or more, further preferably 1000 mass ppm or more, and preferably 3000 mass ppm or less, more preferably 2500 mass ppm or less, and further preferably 2000 mass ppm or less, on a total amount basis of the lubricating oil composition. When the content of the nitrogen component in the lubricating oil composition is within the above-described numerical ranges, it is possible to improve the fuel efficiency while maintaining the caulking resistance.

[0118] The amount of evaporation loss of the lubricating oil composition is preferably 15% by mass or less, more preferably 14% by mass or less, further preferably 13% by mass or less, and particularly preferably 12% by mass or less in terms of NOACK evaporation amount. By setting the NOACK evaporation amount of the lubricating oil composition to be equal to or less than the above-mentioned upper limit, it is possible to suppress the evaporation loss of the lubricating oil small, and it is also possible to suppress viscosity from increasing, etc. Note that, the NOACK evaporation amount as used herein is obtained by measuring the evaporation amount of the lubricating oil measured in accordance with ASTM D 5800.

[EXAMPLES]

[0119] The present invention shall be specifically described below with reference to the Examples and Comparative Examples; however, the present invention shall not be limited to these Examples.

[Preparation of Lubricating Oil Composition]

[0120] Lubricating oil compositions of the present invention (Examples 1 to 10) and lubricating oil compositions for comparison (Comparative Examples 1 to 6) were each prepared by using the lubricating oil base oils and various additives as indicated below in the formulations described in Tables 1 and 2. In Tables 1 and 2, "in mass %" represents % by mass on a total amount basis of the lubricating oil base oil, "mass%" represents % by mass on a total amount basis of the total amount of the lubricating oil composition, and "mass ppm" represents ppm by mass on a total amount basis of the lubricating oil composition.

[(A) Lubricating Oil Base Oil]

[0121]

- A-1 : Hydrocracking base oil (Group III, YUBASE (registered trademark) 4 manufactured by SK Lubricants, density (15 °C): 0.836, kinematic viscosity (40 °C): 19.6mm^2 / s, kinematic viscosity (100 °C) : 4.2mm^2 / s, viscosity index: 122, pour point:-15 °C, sulfur component: less than 10 ppm by mass, % Cp: 80.7, %C_N: 19.3, % C_A: 0)

[0122] Note that, the amount of the lubricating oil base oil is the residual portion obtained by deducting each additive with the total amount of the lubricating oil composition being 100%.

[Additives]

[(B) Calcium-based Detergent]

[0123]

- B-1: Overbased calcium carbonate salicylate (alkyl group chain length 14-18, Ca content: 8.0 mass%, total base number 220 mgKOH / g)

[(C) Magnesium-based Detergent]

[0124]

- C-1: Overbased magnesium carbonate salicylate (alkyl group chain length 14-18, Mg content : 7.6 mass%, total base number 340 mgKOH / g)

[(D) Viscosity Index Improver]

[0125]

- D-1: Styrene-diene copolymer-based viscosity index improver (Mw = 430,000, PSSI = 25)
- D-2: Ethylene-propylene copolymer-based viscosity index improver (Mw = 400,000, PSSI = 24)
- D-3: Non-dispersive poly(meth)acrylate viscosity index improver (Mw = 380,000, PSSI = 25)

[(E) Nitrogen-Containing Dispersant]

[0126]

- E-1: Non-boric acid-modified polybutenyl succinic acid bisimide (Mw = 5200, N content : 1.4% by mass)

[(F)ashless Friction Modifier]

[0127]

- F-1: Glycerin monooleate

[(G) Molybdenum-containing Compound]

[0128]

- G-1: Molybdenum amine (Mo content: 10 mass%, N content: 1.2 mass%)

[(H) Anti-wear Agent]

[0129]

- H-1: Zinc dialkyl dithiophosphate (ZnDTP, secondary alkyl group type, in Formula (10) above, the number of carbon atoms of R^{14} to R^{17} : all 6, Zn content: 9.3% by mass, P content: 8.5% by mass, S content: 18% by mass)

[(I) Antioxidant]

[0130]

- I-1: Diphenylamine

[Property of Lubricating Oil Composition]

[0131] Each of the lubricating oil compositions of Examples 1 to 10 and Comparative Examples 1 to 6 were measured for their various properties as follows. The results are shown in Tables 1 and 2.

- Kinematic viscosity (40 °C, 100 °C): measured according to ASTM D-445.
- Viscosity index : measured according to JIS K 2283-1993.
- HTHS viscosity (150 °C): measured according to ASTM D-4683.
- Content of elements in oil (B, Ca, K, Mg, Mo, Zn, P, Zn): measured according to JIS K 0116-2014.
- Content of sulfur component: measured according to JIS K 2541-2003.
- Content of nitrogen component: measured according to JIS K 2609-1998.

[Table 1]

		Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10
Constitution of Lubricating Oil Composition											
A-1	in mass%	100	100	100	100	100	100	100	100	100	100
B-1	mass%	1.50	1.50	2.00	2.25	1.50	1.50	1.50	1.50	1.50	1.50
C-1	mass%	0.70	0.70	0.15	0.70	0.70	0.70	0.70	0.70	0.70	0.70
D-1	mass%	6.30	3.60	6.30	6.30	-	9.00	1.00	-	3.00	6.30
D-2	mass%	-	-	-	-	6.30	-	-	1.00	3.00	-
D-3	mass%	-	-	-	-	-	-	-	-	-	-
E-1	mass%	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	6.80
F-1	mass%	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
G-1	mass%	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
H-1	mass%	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
I-1	mass%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Property of Lubricating Oil Composition											
Kinematic viscosity (40 °C)	mm^2/s	49.6	38.3	49.7	49.8	46.5	49.8	29.6	29.8	46.3	53.6
Kinematic viscosity (100 °C)	mm^2/s	9.2	7.3	9.2	9.2	8.6	11.1	5.9	5.9	8.6	9.8
Viscosity index		171	161	171	171	167	177	147	146	167	170
HTHS viscosity (150 °C)	mPa·s	2.7	2.3	2.7	2.7	2.7	3.1	2.0	1.9	2.6	2.9
Ca	massppm	1200	1200	1600	1800	1200	1200	1200	1200	1200	1200
Mg	massppm	510	510	120	510	510	510	510	510	510	510
Mo	massppm	200	200	200	200	200	200	200	200	200	200
P	massppm	750	750	750	750	750	750	750	750	750	750
Zn	massppm	820	820	820	820	820	820	820	820	820	820
S	mass%	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
N	massppm	1100	1100	1100	1100	1100	1100	1100	1100	1100	1500

[Table 2]

		Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Constitution of Lubricating Oil Composition							
A-1	inmass%	100	100	100	100	100	100
B-1	mass%	1.50	1.50	2.50	1.25	1.50	1.50
C-1	mass%	0.70	0.70	0.70	0.70	-	0.70
D-1	mass%	-	-	6.30	6.30	6.30	6.30
D-2	mass%	-	-	-	-	-	-
D-3	mass%	8.00	6.30	-	-	-	-
E-1	mass%	5.00	5.00	5.00	5.00	5.00	4.30
F-1	mass%	0.30	0.30	0.30	0.30	0.30	0.30
G-1	mass%	0.20	0.20	0.20	0.20	0.20	0.20
H-1	mass%	0.90	0.90	0.90	0.90	0.90	0.90
I-1	mass%	1.00	1.00	1.00	1.00	1.00	0.10
Property of Lubricating Oil Composition							
Kinematic viscosity (40 °C)	mm^2/s	33.0	31.5	50.2	49.3	48.7	46.4
Kinematic viscosity (100 °C)	mm^2/s	7.3	6.8	9.3	9.2	9.1	8.8
Viscosity index		195	183	170	170	170	172
HTHS viscosity (150 °C)	mPa·s	2.4	2.3	2.7	2.7	2.7	2.6
Ca	massppm	1200	1200	2000	1000	1200	1200
Mg	massppm	510	510	510	510	-	510
Mo	massppm	200	200	200	200	200	200
P	massppm	750	750	750	750	750	750
Zn	massppm	820	820	820	820	820	820

(continued)

Property of Lubricating Oil Composition							
S	mass%	0.16	0.16	0.16	0.16	0.16	0.16
N	massppm	1100	1100	1100	1100	1100	640

[Performance Evaluation of Lubricating Oil Composition]

[0132] Each of the lubricating oil compositions of Examples 1 to 10 and Comparative Examples 1 to 6 was subjected to the following performance evaluation. The evaluation results are shown in Tables 3 and 4.

[Evaluation of Caulking Resistance]

(Panel Caulking Test)

[0133] The lubricating oil compositions were subjected to a panel caulking test. The details of the test method are described below.

[0134] To a testing container with a splasher, 300 mL of a lubricating oil composition was introduced and an aluminum panel was attached. The specimen oil and the panel were heated until the oil temperature of 100 °C and the panel temperature of 300 °C. When the temperature reached the required temperature, the splasher was rotated at 1000 rpm and oil was splashed against the panel. Splashing was done in a cycle of for 15 seconds and then 45 seconds of suspension. After 3 hours, mass (mg) of carbon, etc. was measured which were attached to the aluminum panel.

[Evaluation of LSPI Suppressing performance]

[0135] LSPI frequency index of the lubricating oil composition was calculated in order to evaluate the LSPI suppressing performance. This is a regression equation represented by the following equation (11) reported in SAE Paper 2014-01-2785.

$$\cdot \text{LSP I Frequency Index} = 6.59 \times \text{Ca} - 26.6 \times \text{P} - 5.12 \times \text{Mo} + 1.69 \quad (11)$$

(in formula (11), Ca represents the calcium content (% by mass) in the composition, P represents the phosphorus content (% by mass) in the composition, and Mo represents the molybdenum content (% by mass) in the composition).

[0136] The results show that the lower the LSPI frequency index, the better the LSPI suppression performance.

[Evaluation of High-temperature Cleaning Properties]

(Hot Tube Test)

[0137] The lubricating oil composition was subjected to a hot tube test in accordance with JPI-5S-55-99. The test method is described in detail below.

[0138] In a glass tube having an inner diameter of 2 mm, a lubricating oil composition was flowed at 0.3 ml / hour and air at 10 ml / second for 16 hours while keeping the temperature of the glass tube at 280 °C. The lacquer attached to the glass tube was compared with the color sample, and scores were given as 10 for transparent and 0 for black.

[0139] The higher the score indicates the better the high-temperature cleaning properties. If the score is 7.0 or more, it can be said that the high-temperature cleaning properties are good.

[Table 3]

Performance Evaluation of Lubricating Oil Composition		Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10
Panel Caulking Test	mg	100	58	90	81	138	119	31	33	53	44
LSPI		0.3834	0.3834	0.647	0.7788	0.3834	0.3834	0.3834	0.3834	0.3834	0.3834
Hot Tube Test	mass%	7.0	7.0	7.0	7.5	7.0	7.0	7.0	7.0	7.0	7.5
	mg	0.5	0.5	0.2	0.0	0.5	0.2	0.0	0.1	0.1	0.2

[Table 4]

Performance Evaluation of Lubricating Oil Composition		Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Panel Caulking Test	mg	204	250	76	69	21	100
LSPI		0.3834	0.3834	0.9106	0.2516	0.3834	0.3834
Hot Tube Test	mass%	7.0	7.0	8.0	6.0	3.0	5.5
	mg	0.4	0.0	0.0	0.2	0.2	0.8

[0140] The lubricating oil compositions of Examples 1-10 showed good results in caulking resistance, LSPI suppression performance, and high temperature cleaning properties.

[0141] On the other hand, the lubricating oil compositions of Comparative Examples 1 and 2 in which the same poly(meth)acrylate-based viscosity index improver is used as the conventional engine oil for the viscosity index improver showed poor results in caulking resistance.

[0142] The lubricating oil composition of Comparative Example 3 in which the calcium content was excessive showed poor results in LSPI suppression performance.

[0143] All of the lubricating oil composition of Comparative Example 4 in which the calcium content is excessively small, the lubricating oil composition of Comparative Example 5 which is free of magnesium, and the lubricating oil composition of Comparative Example 6 with excessively small content of nitrogen in the lubricating oil composition had poor results in the high temperature cleaning properties.

Claims

1. A lubricating oil composition for a super-charged engine, comprising:

   (A) a lubricating oil base oil;
   (B) a calcium-based cleaning agent, wherein the calcium amount is 1100 mass ppm or more to 1900 mass ppm or less on a total amount basis of the lubricating oil composition;
   (C) a magnesium-based cleaning agent; and
   (D) at least one viscosity index improver selected from a styrene-diene copolymer and an ethylene-α-olefin copolymer; and
   (E) a nitrogen-containing dispersing agent;

   and containing 700 mass ppm or more of a nitrogen component, on a total amount basis of the lubricating oil composition.

2. The lubricating oil composition according to claim 1, wherein
   the (B) calcium-based cleaning agent is calcium salicylate.

3. The lubricating oil composition according to claim 1 or 2, wherein
   the (C) magnesium-based cleaning agent is magnesium salicylate.

4. The lubricating oil composition according to any one of claims 1 to 3, wherein
   the content of the (C) magnesium-based cleaning agent is 100 ppm by mass or more to 1000 ppm by mass or less as a magnesium amount on a total amount basis of the lubricating oil composition.

5. The lubricating oil composition according to any one of claims 1 to 4, wherein
   the viscosity index improver (D) is a styrene-diene copolymer.

6. The lubricating oil composition according to any one of claims 1 to 5, wherein
   the content of the (D) viscosity index improver is 0.1% by mass or more to 20% by mass or less on a total amount basis of the lubricating oil composition.

7. The lubricating oil composition according to any one of claims 1 to 6, further comprising (F) an ashless friction modifier.

8. The lubricating oil composition according to any one of claims 1 to 7, further comprising (G) a molybdenum-containing compound.

9. The lubricating oil composition according to any one of claims 1 to 8, further comprising zinc alkylphosphate as (H) an anti-wear agent.

10. The lubricating oil composition according to any one of claims 1 to 9, wherein
    the kinematic viscosity at 100 °C is $4.0mm^2 / s$ or more and less than $12.5mm^2 / s$.

11. The lubricating oil composition according to any one of claims 1 to 10, wherein
    the HTHS viscosity at 150 °C is 1.7 mPa·s or more and less than 3.5 mPa·s.

12. The lubricating oil composition according to any one of claims 1 to 11, wherein
the lubricating oil composition is free of poly(meth)acrylate as a viscosity index improver.

13. The lubricating oil composition according to any one of claims 1 to 12, wherein
the content of nitrogen component is 1000 ppm by mass or more on a total amount basis of the composition.

14. The lubricating oil composition according to any one of claims 1 to 13 for use in both gasoline and diesel engines.

15. The lubricating oil composition of any one of claims 1 to 13, for use in a diesel engine.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/043464

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. C10M161/00(2006.01)i, C10M129/54(2006.01)n, C10M133/00(2006.01)n, C10M137/06(2006.01)n, C10M139/00(2006.01)n, C10M143/00(2006.01)n, C10M143/10(2006.01)n, C10N20/02(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. C10M101/00-177/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2019
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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2015-163673 A (TONENGENERAL SEKIYU KK) 10 September 2015, claims, paragraphs [0018], [0023], [0051], [0056]-[0060], [0089]-[0094], [0103], [0104], [0114], tables 2, 5, example 11 & EP 3101095 A1, claims, paragraphs [0021], [0026], [0054], [0059]-[0063], [0072], [0073], [0095]-[0100], [0110]-[0117], tables 2, 5, example 11 & US 2017/0022441 A1 & WO 2015/114920 A1 & CN 106164229 A	1-15

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

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"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search 11.12.2019	Date of mailing of the international search report 24.12.2019
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/JP2019/043464

C (Continuation). 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, paragraphs [0004], [0044], table 1, comparative examples 1-4 (Family: none)	1-15
Y	WO 2016/159216 A1 (IDEMITSU KOSAN CO., LTD.) 06 October 2016, claim 1, paragraph [0062], examples 1-9, table 2 & US 2017/0121627 A1, claim 1, paragraph [0142], examples 1-9, table 2 & KR 10-2017-0132732 A & JP 2016-193996 A & EP 3279299 A1 & CN 106414687 A	14-15
A	JP 10-147790 A (TONEN CORPORATION) 02 June 1998, claims, paragraphs [0014], [0016], table 1, examples 1-3 (Family: none)	1-15

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

REFERENCES CITED IN THE DESCRIPTION

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- JP 2003155492 A **[0005]**
- JP 2015163673 A **[0005]**