

LUBRICATING OIL COMPOSITION

Technical Field

[0001] The present invention relates to lubricating oil compositions.

Background Art

[0002] Conventionally, lubricating oil has been used in an internal combustion engine, a transmission or other mechanical devices to facilitate the smooth operation thereof. In particular, a lubricating oil (engine oil) for an internal combustion engine is required to have a high level of performances because the internal combustion engine has been improved in performance, enhanced in output and used under severe working conditions. Therefore, conventional engine oils have been blended with various additives such as antiwear agents, metallic detergents, ashless dispersants, and anti-oxidants to meet such requisite performances (for example, see Patent Literatures 1 to 3 below). Furthermore, recently the fuel saving performance of the lubricating oil has been required to be increasingly better and better, and thus applications of a high viscosity index base oil or various friction modifiers have been studied (for example, see Patent Literature 4 below).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Patent
Application Publication No. 2001-279287

Patent Literature 2: Japanese Patent
Application Publication No. 2002-129182

Patent Literature 3: Japanese Patent
Application Laid-Open Publication No. 08-302378

Patent Literature 4: Japanese Patent
Application Laid-Open Publication No. 06-306384

Summary of Invention

Technical Problem

[0004] However, the conventional lubricating oils cannot be necessarily deemed sufficient in terms of fuel saving properties.

As general fuel saving techniques, it is known to reduce the kinematic viscosity of lubricating oil and enhance the viscosity index thereof (multi-grading that is a combination of a low viscosity base oil and a viscosity index improver) and also to blend a friction reducing agent. For the viscosity reduction, a reduction in the viscosity of a lubricating oil or the base oil thereof degrades the lubricating properties under severe lubricating conditions (high temperature and high shear

conditions), and thus has been concerned to cause defects such as wear, seizure, or fatigue breaking. With regard to the blending of a friction reducing agent, it is known to add an ashless or molybdenum friction modifier. However, a fuel saving oil has still been sought, which is further superior to the conventional friction reducing agent-blended oil.

[0005] In order to prevent these defects caused by reducing the viscosity of a lubricating oil or the base oil thereof to maintain the durability of an engine and further to impart fuel saving properties to the oil, it is advantageously effective to maintain the 150°C HTHS viscosity ("HTHS viscosity" is also referred to as "high temperature high shear viscosity") higher and maintain the 40°C kinematic viscosity, 100°C kinematic viscosity and 100°C HTHS viscosity lower. However, it has been difficult to satisfy all of these requirements with the conventional lubricating oils.

However, due to recent development of engine technologies, it has become possible for a lubricating oil to be reduced in the 150°C HTHS viscosity but still to retain the durability of an engine. To further improve the fuel saving properties, an engine oil having a 150°C HTHS viscosity of below 2.6 mPa·s which is the lower limit 150°C HTHS viscosity, for example

of an SAE OW-20 engine oil has been developed and applied. However, the engine oil having a 150°C HTHS viscosity of below 2.6 mPa·s has been confirmed to increase the friction coefficient of a boundary lubrication region where metal parts in some engines or components contact each other and thus to adversely affect the fuel saving properties.

A technology to reduce the friction coefficient in the boundary lubrication region more than before is needed so as to enhance the fuel saving properties of all of the engines to which an engine oil having a 150°C HTHS viscosity of below 2.6 mPa·s is applied.

[0006] The present invention has been made in view of such situations and has an object to provide a lubricating oil composition that is an engine oil having a 150°C HTHS viscosity of lower than 2.6 mPa·s, can be reduced sufficiently in the 40°C kinematic viscosity, 100°C kinematic viscosity and 100°C HTHS viscosity and suppress the increase of the friction coefficient in a boundary lubrication region and has excellent fuel saving properties for an engine having a tough boundary lubrication region.

Solution to Problem

[0007] In order to achieve the above object, the

present invention provides a lubricating oil composition comprising a lubricating base oil with a 100°C kinematic viscosity of 1 to 5 mm²/s, (A) a viscosity index improver with a weight average molecular weight of 400,000 or less and a PSSI of 20 or less, (B) an overbasic metallic detergent with a metal ratio of 3.4 or less and (C) a friction modifier, and having a 150°C HTHS viscosity of lower than 2.6 mPa·s.

[0008] The above (A) viscosity index improver is preferably a viscosity index improver with a ratio of the weight-average molecular weight and PSSI (Mw/PSSI) of 1×10^4 or greater.

[0009] The above (B) overbasic metallic detergent is preferably an overbasic alkaline earth metal salicylate produced by overbasing an alkaline earth metal salicylate with an alkaline earth metal borate.

[0010] The above (C) friction modifier is preferably an organic molybdenum friction modifier.

[0011] The term "PSSI" used herein denotes the permanent shear stability index of a polymer calculated on the basis of the data measured with ASTM D 6278-02 (Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus) in conformity with ASTM D 6022-01 (Standard Practice for

Calculation of Permanent Shear Stability Index).

Advantageous Effect of Invention

[0012] The present invention can provide a lubricating oil composition that is an engine oil having a 150°C HTHS viscosity of lower than 2.6 mPa·s, can reduce sufficiently the 40°C kinematic viscosity, 100°C kinematic viscosity and 100°C HTHS viscosity and suppress the friction coefficient in a boundary lubrication region from increasing and has excellent fuel saving properties.

[0013] The lubricating oil composition of the present invention is suitably used in gasoline engines, diesel engines and gas engines for two- and four-wheeled vehicles, power generators and cogenerations and further not only those using fuel with a sulfur content of 50 ppm by mass or less but also various engines of ships and outboard motors.

Description of Embodiments

[0014] Hereinafter, suitable embodiments of the present invention will be described.

[0015] The lubricating oil composition according to the present invention comprises a lubricating base oil with a 100°C kinematic viscosity of 1 to 5 mm²/s, (A) a viscosity index improver with a weight average molecular weight of 400,000 or less and a PSSI of 20

or less, (B) an overbasic metallic detergent with a metal ratio of 3.4 or less and (C) a friction modifier.

[0016] The lubricating oil composition of the present invention contains a lubricating base oil having a 100°C kinematic viscosity of 1 to 5 mm²/s (hereinafter referred to as "the lubricating base oil of the present invention").

[0017] Examples of the lubricating base oil of the present invention include those having a 100°C kinematic viscosity of 1 to 5 mm²/s selected from: paraffinic mineral base oils which can be produced by subjecting a lubricating oil fraction produced by atmospheric- and/or vacuum-distillation of a crude oil, to any one of or any suitable combination of refining processes selected from solvent deasphalting, solvent extraction, hydrocracking, hydroisomerizing, solvent dewaxing, catalytic dewaxing, hydrotreating, sulfuric acid treatment, and clay treatment; n-paraffinic base oils; and iso-paraffinic base oils.

[0018] Examples of preferred lubricating base oils include base oils produced using the following base oils (1) to (8) as a feedstock by refining the feedstock and/or a lubricating oil fraction recovered therefrom in a given refining process and recovering a lubricating oil fraction:

(1) a distillate oil produced by atmospheric distillation of a paraffin-base crude oil and/or a mixed-base crude oil;

(2) a whole vacuum gas oil (WVGO) produced by vacuum distillation of the topped crude of a paraffin-base crude oil and/or a mixed-base crude oil;

(3) a wax produced by dewaxing of lubricating oil (slack wax) and/or a synthetic wax produced through a gas to liquid (GTL) process (Fischer-Tropsch wax, GTL wax);

(4) a mixed oil of one or more types selected from base oils (1) to (3) and/or an oil produced by mild-hydrocracking the mixed oil;

(5) a mixed oil of two or more types selected from base oils (1) to (4) above;

(6) a deasphalted oil (DAO) produced by deasphalting base oil (1), (2) (3), (4) or (5);

(7) an oil produced by mild-hydrocracking (MHC) base oil (6); and

(8) a mixed oil of two or more types selected from base oils (1) to (7) above.

[0019] The above-mentioned given refining process is preferably hydro-refining such as hydrocracking or hydrofinishing, solvent refining such as furfural extraction, dewaxing such as solvent dewaxing and

catalytic dewaxing, clay refining with acidic clay or active clay or chemical (acid or alkali) refining such as sulfuric acid treatment and sodium hydroxide treatment. In the present invention, any one or more of these refining processes may be used in any combination and order.

[0020] The lubricating base oil used in the present invention is particularly preferably the following base oil (9) or (10) produced by subjecting a base oil selected from the above-described base oils (1) to (8) or a lubricating oil fraction recovered therefrom to a specific treatment:

(9) a hydrocracked base oil produced by hydrocracking a base oil selected from base oils (1) to (8) or a lubricating oil fraction recovered from the base oil, and subjecting the resulting product or a lubricating oil fraction recovered therefrom by distillation, to a dewaxing treatment such as solvent or catalytic dewaxing, optionally followed by distillation; or

(10) a hydroisomerized base oil produced by hydroisomerizing a base oil selected from base oils (1) to (8) or a lubricating oil fraction recovered from the base oil, and subjecting the resulting product or a lubricating oil fraction recovered therefrom by

distillation, to a dewaxing treatment such as solvent or catalytic dewaxing, optionally followed by distillation.

[0021] If necessary, a solvent refining process and/or a hydrofinishing process may be carried out at appropriate timing upon production of lubricating base oil (9) or (10).

[0022] No particular limitation is imposed on the catalyst used in the above-described hydrocracking and hydroisomerizing. However, the catalyst is preferably a hydrocracking catalyst comprising any one of complex oxides having cracking activity (for example, silica-alumina, alumina boria, or silica zirconia) or one or more types of such complex oxides bound with a binder, used as a support and a metal with hydrogenation capability (for example, one or more types of metals of Groups VIa and VIII of the periodic table) supported on the support, or a hydroisomerizing catalyst comprising a support containing zeolite (for example, ZSM-5, zeolite beta, or SAPO-11) and a metal with hydrogenation capability, containing at least one or more types of metals of Group VIII of the periodic table and supported on the support. The hydrocracking and hydroisomerizing catalysts may be laminated or mixed so as to be used in combination.

[0023] No particular limitation is imposed on the conditions under which the hydrocracking and hydroisomerizing are carried out. Preferably, the hydrogen partial pressure is from 0.1 to 20 MPa, the average reaction temperature is from 150 to 450°C, the LHSV is from 0.1 to 3.0 hr⁻¹, and the hydrogen/oil ratio is from 50 to 20000 scf/b.

[0024] The 100°C kinematic viscosity of the lubricating base oil of the present invention is necessarily 5 mm²/s or lower, preferably 4.5 mm²/s or lower, more preferably 4 mm²/s or lower, more preferably 3.8 mm²/s or lower, particularly preferably 3.7 mm²/s or lower, most preferably 3.6 mm²/s or lower. Whilst, the 100°C kinematic viscosity is necessarily 1 mm²/s or higher, preferably 1.5 mm²/s or higher, more preferably 2 mm²/s or higher, more preferably 2.5 mm²/s or higher, particularly preferably 3 mm²/s. The 100°C kinematic viscosity used herein refers to the 100°C kinematic viscosity determined in accordance with ASTM D-445. If the 100°C kinematic viscosity of the lubricating base oil exceeds 5 mm²/s, the resulting composition would be degraded in low temperature viscosity characteristics and may not obtain sufficiently improved fuel saving properties. If the 100°C kinematic viscosity is lower than 1 mm²/s, the

resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss of the composition.

[0025] The 40°C kinematic viscosity of the lubricating base oil of the present invention is preferably 40 mm²/s or lower, more preferably 30 mm²/s or lower, more preferably 25 mm²/s or lower, particularly preferably 20 mm²/s or lower, most preferably 17 mm²/s or lower. Whilst, the 40°C kinematic viscosity is preferably 6.0 mm²/s or higher, more preferably 8.0 mm²/s or higher, more preferably 10 mm²/s higher, particularly preferably 12 mm²/s or higher, most preferably 14 mm²/s or higher. If the 40°C kinematic viscosity of the lubricating base oil exceeds 40 mm²/s, the resulting composition would be degraded in low temperature viscosity characteristics and may not obtain sufficiently improved fuel saving properties. If the 40°C kinematic viscosity is lower than 6.0 mm²/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss of the composition.

[0026] The viscosity index of the lubricating base

oil of the present invention is preferably 100 or greater, more preferably 105 or greater, more preferably 110 or greater, particularly preferably 115 or greater, most preferably 120 or greater. Whilst, the viscosity index is 180 or less, more preferably 170 or less, more preferably 160 or less. A viscosity index of less than 100 would not only cause the viscosity-temperature characteristics, thermal/oxidation stability, anti-evaporation properties to degrade but also cause the friction coefficient to increase and likely cause the friction coefficient to increase and cause the anti-wear properties to degrade. A viscosity index of greater than 180 would tend to degrade the low temperature fluidity.

[0027] The viscosity index referred herein denotes the viscosity index measured in accordance with JIS K 2283-1993.

[0028] The lubricating base oil used in the lubricating oil composition of the present invention is preferably a mixture of a first lubricating base oil component having a 100°C kinematic viscosity of 3.5 mm²/s or higher and a second lubricating base oil component having a 100°C kinematic viscosity of lower than 3.5 mm²/s. Mixing of the first lubricating base

oil component and second lubricating base oil component would provide the resulting lubricating oil composition with excellent viscosity temperature characteristics and thus further improve the fuel saving properties thereof.

[0029] The 15°C density (ρ_{15}) of the first lubricating base oil component used in the lubricating oil composition of the present invention is preferably 0.860 g/cm³ or lower, more preferably 0.850 g/cm³ or lower, more preferably 0.840 g/cm³ or lower, particularly preferably 0.822 g/cm³ or lower.

The 15°C density referred in the present invention denotes the density measured at 15°C in accordance with JIS K 2249-1995.

[0030] The pour point of the first lubricating base oil component used in the lubricating oil composition of the present invention is preferably -10°C or lower, more preferably -12.5°C or lower, more preferably -15°C or lower, particularly preferably -20°C or lower. If the pour point is higher than -10°C, the whole lubricating oil containing such a lubricating base oil would tend to be degraded in low temperature fluidity. The pour point referred in the present invention is the pour point measured in accordance with JIS K 2269-1987.

[0031] The 100°C kinematic viscosity of the first

lubricating base oil component used in the lubricating oil composition of the present invention is preferably 5 mm²/s or lower, more preferably 4.5 mm²/s or lower, more preferably 4.0 mm²/s or lower, particularly preferably 3.9 mm²/s or lower. Whilst, the 100°C kinematic viscosity is preferably 3.5 mm²/s or higher, more preferably 3.6 mm²/s or higher, more preferably 3.7 mm²/s or higher, particularly preferably 3.8 mm²/s or higher. If the 100°C kinematic viscosity exceeds 5 mm²/s, the resulting composition would be degraded in low temperature viscosity characteristics and may not obtain sufficiently improved fuel saving properties. If the 100°C kinematic viscosity is lower than 3.5 mm²/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss of the composition.

[0032] The 40°C kinematic viscosity of the first lubricating base oil component used in the lubricating oil composition of the present invention is preferably 40 mm²/s or lower, more preferably 30 mm²/s or lower, more preferably 25 mm²/s or lower, particularly preferably 20 mm²/s or lower, most preferably 17 mm²/s or lower. Whilst, the 40°C kinematic viscosity is

preferably 6.0 mm²/s or higher, more preferably 8.0 mm²/s or higher, more preferably 10 mm²/s or higher, particularly preferably 12 mm²/s or higher, most preferably 14 mm²/s or higher. If the 40°C kinematic viscosity exceeds 40 mm²/s, the resulting composition would be degraded in low temperature viscosity characteristics and may not obtain sufficiently improved fuel saving properties. If the 40°C kinematic viscosity is lower than 6.0 mm²/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss of the composition.

[0033] The viscosity index of the first lubricating base oil component used in the lubricating oil composition of the present invention is preferably 100 or greater, more preferably 110 or greater, more preferably 120 or greater, particularly preferably 130 or greater, most preferably 140 or greater. A viscosity index of less than 100 would not only cause the viscosity-temperature characteristics, thermal/oxidation stability, anti-evaporation properties to degrade but also likely cause the friction coefficient to increase and cause the anti-wear properties to degrade.

[0034] The 15°C density (ρ_{15}) of the second lubricating base oil component used in the lubricating oil composition of the present invention is preferably 0.860 g/cm³ or lower, more preferably 0.850 g/cm³ or lower, more preferably 0.840 g/cm³ or lower, particularly preferably 0.835 g/cm³ or lower.

[0035] The pour point of the second lubricating base oil component used in the lubricating oil composition of the present invention is preferably -10°C or lower, more preferably -12.5°C or lower, more preferably -15°C or lower, particularly preferably -20°C or lower. If the pour point is higher than -10°C, the whole lubricating oil containing such a lubricating base oil would tend to be degraded in low temperature fluidity. The pour point referred in the present invention is the pour point measured in accordance with JIS K 2269-1987.

[0036] The 100°C kinematic viscosity of the second lubricating base oil component used in the lubricating oil composition of the present invention is preferably lower than 3.5 mm²/s, more preferably 3.4 mm²/s or lower, more preferably 3.3 mm²/s or lower. Whilst, the 100°C kinematic viscosity is preferably 1 mm²/s or higher, more preferably 2 mm²/s or higher, more preferably 2.5 mm²/s or higher, particularly preferably 3.0 mm²/s or higher. If the 100°C kinematic viscosity is lower than

1 mm²/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss of the composition.

[0037] The 40°C kinematic viscosity of the second lubricating base oil component used in the lubricating oil composition of the present invention is preferably 20 mm²/s or lower, more preferably 18 mm²/s or lower, more preferably 16 mm²/s or lower, particularly preferably 14 mm²/s or lower. Whilst, the 40°C kinematic viscosity is preferably 6.0 mm²/s or higher, more preferably 8.0 mm²/s or higher, more preferably 10 mm²/s or higher, particularly preferably 12 mm²/s or higher, most preferably 13 mm²/s or higher. If the 40°C kinematic viscosity exceeds 20 mm²/s, the resulting composition would be degraded in low temperature viscosity characteristics and may not obtain sufficiently improved fuel saving properties. If the 40°C viscosity is lower than 6.0 mm²/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss of the composition.

[0038] The viscosity index of the second lubricating base oil component used in the lubricating

oil composition of the present invention is preferably 100 or greater, more preferably 105 or greater, more preferably 110 or greater. A viscosity index of less than 100 would not only cause the viscosity-temperature characteristics, thermal/oxidation stability, anti-evaporation properties to degrade but also likely cause the friction coefficient to increase and cause the anti-wear properties to degrade.

[0039] The sulfur content of the lubricating base oil used in the present invention depends on the sulfur content of the raw material thereof. For example, when a raw material containing substantially no sulfur such as a synthetic wax component produced by Fischer-Tropsch reaction is used, a lubricating base oil containing substantially no sulfur can be produced. Alternatively, when a raw material containing sulfur such as slack wax produced through a refining process of a lubricating base oil or micro wax produced through wax refining is used, the sulfur content of the resulting lubricating base oil is usually 100 mass ppm or more. The sulfur content of the lubricating base oil used in the present invention is preferably 100 mass ppm or less, more preferably 50 mass ppm or less, more preferably 10 mass ppm or less, particularly preferably 5 mass ppm or less with the objective of further

improving thermal/oxidation stability and lowering the sulfur content.

[0040] The nitrogen content of the lubricating base oil used in the present invention is preferably 7 mass ppm or less, more preferably 5 mass ppm or less, more preferably 3 mass ppm or less. If the nitrogen content exceeds 7 mass ppm, the resulting composition would tend to be degraded in thermal/oxidation stability. The nitrogen content referred in the present invention denotes the nitrogen content measured in accordance with JIS K 2609-1990.

[0041] The %C_P of the lubricating base oil used in the present invention is preferably 70 or greater, more preferably from 80 to 99, more preferably from 85 to 95, particularly preferably from 87 to 94, most preferably from 90 to 94. If the %C_P of the lubricating base oil is less than 70, the resulting composition would tend to be degraded in viscosity-temperature characteristics, thermal/oxidation stability and friction characteristics and when blended with additives, would tend to degrade the efficacy thereof. If the %C_P of the lubricating base oil exceeds 99, the solubility of additives would tend to be degraded.

[0042] The %C_A of the lubricating base oil used in the present invention is preferably 2 or less, more

preferably 1 or less, more preferably 0.8 or less, particularly preferably 0.5 or less. If the %CA of the lubricating base oil exceeds 2, the resulting composition would tend to be degraded in viscosity-temperature characteristics, thermal/oxidation stability and fuel saving properties.

[0043] The %C_N of the lubricating base oil used in the present invention is preferably 30 or less, more preferably from 4 to 25, more preferably from 5 to 13, particularly preferably from 5 to 8. If the %C_N of the lubricating base oil exceeds 30, the resulting composition would tend to be degraded in viscosity-temperature characteristics, thermal/oxidation stability and friction characteristics. If the %C_N is less than 4, the solubility of additives would tend to degrade.

[0044] The %C_P, %C_N, and %C_A referred in the present invention denote the percentage of paraffin carbon number in the total carbon number, the percentage of naphthene carbon number in the total carbon number, and the percentages of the aromatic carbon number in the total carbon number, respectively, determined by a method (n-d-M ring analysis) in accordance with ASTM D 3238-85. Specifically, the above-described

preferred ranges of the %C_P, %C_N and %C_A are based on the values determined by the above-described method, and for example, even if a lubricating base oil does not contain naphthene, the %C_N may represent the value of exceeding 0.

[0045] The saturate content of the lubricating base oil used in the present invention is preferably 90 percent by mass or more, preferably 95 percent by mass or more, more preferably 99 percent by mass or more on the basis of the total mass of the lubricating base oil. The ratio of the cyclic saturate content of the saturate content is preferably 40 percent by mass or less, preferably 35 percent by mass or less, preferably 30 percent by mass or less, more preferably 25 percent by mass or less, more preferably 21 percent by mass or less. The ratio of the cyclic saturate content of the saturate content is preferably 5 percent by mass or more, more preferably 10 percent by mass or more. The saturate content and ratio of cyclic saturate content therein of a lubricating base oil satisfying the above-described conditions can provide a lubricating oil composition that can be enhanced in viscosity-temperature characteristics and thermal/oxidation stability and when the lubricating base oil is blended with additives, can retain the

additives in the lubricating base oil sufficiently stably dissolved, allowing the additives to exhibit their functions in a higher level. Furthermore, according to the present invention, the lubricating base oil itself can be improved in friction characteristics and as the result improved in friction reducing effect and moreover achieve the improvement in energy saving properties.

[0046] The saturate content referred in the present invention is measured in accordance with the method described in the aforesaid ASTM D 2007-93.

Upon separation of the saturate or analysis of the cyclic saturate and non-cyclic saturate, similar methods that can provide similar results can be used. Examples of such methods include the methods described in ASTM D 2425-93 and ASTM D 2549-91, a method using high-performance liquid chromatography (HPLC) and methods obtained by improving these methods.

[0047] The aromatic content of the lubricating base oil of the present invention is preferably 5 percent by mass or less, more preferably 4 percent by mass or less, more preferably 3 percent by mass or less, particularly preferably 2 percent by mass or less and preferably 0.1 percent by mass or more, more preferably 0.5 percent by mass or more, more preferably 1 percent

by mass or more, particularly preferably 1.5 percent by mass or more. If the aromatic content exceeds 5 percent by mass, the resulting composition would tend to be degraded in viscosity-temperature characteristics, thermal/oxidation stability and friction characteristics, and furthermore in anti-volatile properties and low temperature viscosity characteristics and when blended with additives, would tend to reduce the efficacy thereof. The lubricating base oil of the present invention may not contain aromatics. Adjusting the aromatic content to 0.1 percent by mass or more can further enhance the solubility of additives.

[0048] The aromatic content referred herein denotes the value measured in accordance with ASTM D 2007-93. The aromatics includes alkylbenzenes; alkylnaphthalens; anthracene, phenanthrene, and alkylated products thereof; compounds wherein four or more benzene rings are condensated to each other; and compounds having hetero atoms such as pyridines, quinolines, phenols, and naphthols.

[0049] The lubricating base oil of the present invention may be a synthetic base oil. Examples of the synthetic base oil include those having a 100°C kinematic viscosity of 1 to 5 mm²/s such as

poly- α -olefins and hydrogenated compounds thereof; isobutene oligomers and hydrogenated compounds thereof; isoparaffins; alkylbenzenes; alkylnaphthalenes; diesters such as ditridecyl glutarate, di-2-ethylhexyl adipate, diisodecyl adipate, ditridecyl adipate and di-2-ethylhexyl sebacate; polyol esters such as trimethylolpropane caprylate, trimethylolpropane pelargonate, pentaerythritol 2-ethylhexanoate and pentaerythritol pelargonate; polyoxyalkylene glycols; dialkyldiphenyl ethers; and polyphenyl ethers. Preferred synthetic lubricating base oils are poly- α -olefins. Typical examples of poly- α -olefins include oligomers or cooligomers of α -olefins having 2 to 32, preferably 6 to 16 carbon atoms, such as 1-octene oligomer, decene oligomer, ethylene-propylene cooligomer, and hydrogenated compounds thereof.

[0050] No particular limitation is imposed on the method of producing poly- α -olefins. For example, poly- α -olefins may be produced by polymerizing α -olefins in the presence of a polymerization catalyst such as a Friedel-Crafts catalyst containing aluminum trichloride, or a complex of boron trifluoride with water, an alcohol such as ethanol, propanol and butanol, a carboxylic acid or an ester.

[0051] The above lubricating base oils of the present invention may be used alone or in combination with one or more type of other base oil. When the base oil of the present invention is used in combination with the other base oils, the proportion of the base oil of the present invention in the mixed base oil is preferably 30 percent by mass or more, more preferably 50 percent by mass or more, more preferably 70 percent by mass or more.

[0052] No particular limitation is imposed on the other base oils used in combination with the base oil of the present invention. Examples of the mineral base oil include solvent-refined mineral oils, hydrocracked mineral oils, hydrorefined mineral oils, and solvent-dewaxed base oils, all of which have a 100°C kinematic viscosity of higher than 5 mm²/s and 100 mm²/s or lower.

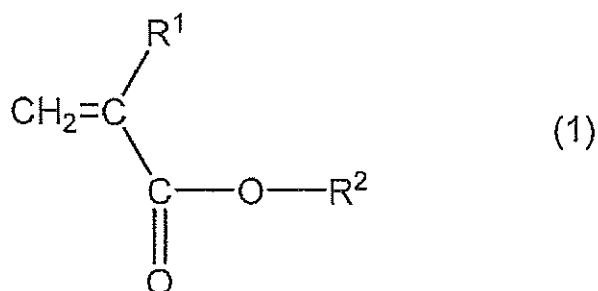
Examples of the synthetic base oil include the above-described synthetic base oils which, however, have a 100°C kinematic viscosity outside the range of 1 to 5 mm²/s.

[0053] The lubricating oil composition of the present invention comprises (A) a viscosity index improver with a weight average molecular weight of 400,000 or less and a PSSI of 20 or less. Whereby, the

lubricating oil composition of the present invention can be enhanced in fuel saving properties compared with a composition not containing such a viscosity index improver. The viscosity index improver may take any format if it satisfies the conditions where the Mw is 400,000 or less and the PSSI is 20 or less. Specific examples of the compound include non-dispersant type or dispersant type ester group-containing viscosity index improvers, non-dispersant type or dispersant type poly(meth)acrylate viscosity index improvers, styrene-diene hydrogenated copolymers, non-dispersant type or dispersant type ethylene- α -olefin copolymers or hydrogenated compounds thereof, polyisobutylene and hydrogenated compounds thereof, styrene-maleic anhydride ester copolymer, polyalkylstyrenes, (meth)acrylate-olefin copolymers and mixtures thereof.

[0054] The poly(meth) acrylate viscosity index improver ("poly(meth)acrylate" used herein refers collectively to polyacrylate compounds and polymethacrylate compounds) that may be used as a viscosity index improver in the present invention is a polymer of a polymeric monomer containing a (meth)acrylate monomer (hereinafter referred to as "Monomer M-1") represented by formula (1) below.

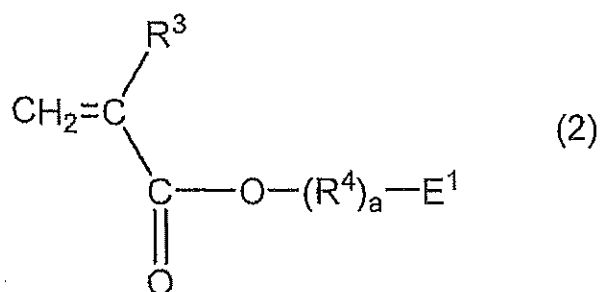
[0055]



In formula (1) above, R¹ is hydrogen or methyl and R² is a straight-chain or branched hydrocarbon group having 1 to 5000 carbon atoms.

[0056] The poly(meth)acrylate compounds produced by homopolymerizing a monomer represented by formula (1) or copolymerizing two or more types of monomers represented by formula (1) are so-called non-dispersant type poly(meth)acrylates. However, the poly(meth)acrylate compound used in the present invention may be so-called dispersant type poly(meth)acrylates produced by copolymerizing a monomer represented by formula (1) with one or more monomers selected from the group consisting of monomers represented by formula (2) below and monomers represented by formula (3) below (hereinafter referred to as "Monomer M-2" and Monomer M-3", respectively).

[0057]



In formula (2) above, R³ is hydrogen or methyl, R⁴ is an alkylene group having 1 to 18 carbon atoms, E¹ is an amine residue or heterocyclic residue having 1 or 2 nitrogen atoms and 0 to 2 oxygen atoms, and a is an integer of 0 or 1.

[0058]



In formula (3), R⁵ is hydrogen or methyl, and E² is an amine residue or heterocyclic residue having 1 or 2 nitrogen atoms and 0 to 2 oxygen atoms.

[0059] Specific examples of the amine residue or heterocyclic residue represented by E¹ and E² include dimethylamino, diethylamino, dipropylamino, dibutylamino, anilino, toluidino, xylidino, acetylamino, benzoilamino, morpholino, pyrrolyl,

pyrrolino, pyridyl, methylpyridyl, pyrrolidinyl, piperidinyl, quinonyl, pyrrolidonyl, pyrrolidono, imidazolino and pyrazino groups.

[0060] Specific preferable examples of Monomer M-2 and Monomer M-3 include dimethylaminomethylmethacrylate, diethylaminomethylmethacrylate, dimethylaminoethylmethacrylate, diethylaminoethylmethacrylate, 2-methyl-5-vinylpyridine, morpholinomethylmethacrylate, morpholinoethylmethacrylate, N-vinylpyrrolidone, and mixtures thereof.

[0061] No particular limitation is imposed on the copolymerization molar ratio of Monomer M-1, and Monomers M-2 and M-3 in a copolymer. However, M-1:M-2 and M-3 is preferably from 99:1 to 80:20, more preferably 98:2 to 85:15, more preferably 95:5 to 90:10.

[0062] The styrene-diene hydrogenated copolymer that may be used as the viscosity index improver in the present invention is a compound produced by hydrogenating a copolymer of styrene and diene. Specific examples of the diene include butadiene and isoprene. Particularly preferred is a hydrogenated

copolymer of styrene and isoprene.

[0063] The ethylene- α -olefin copolymer or a hydrogenated compound thereof that may be used as the viscosity index improver in the present invention is a copolymer of ethylene and an α -olefin or a compound produced by hydrogenating the copolymer.

Specific examples of the α -olefin include propylene, isobutylene, 1-butene, 1-pentene, 1-hexene, 1-octene, 1-decene, and 1-dodecene. The ethylene- α -olefin copolymer may be a copolymer consisting of hydrocarbons that is of non-dispersant type or a copolymer produced by reacting a copolymer with a polar compound such as a nitrogen-containing compound that is a dispersant-type ethylene- α -olefin copolymer.

[0064] The viscosity index improver used in the present invention has a weight-average molecular weight (MW) of necessarily 400,000 or less, preferably 380,000 or less, more preferably 360,000 or less. The viscosity index improver has a weight-average molecular weight of preferably 10,000 or greater, more preferably 50,000 or greater, more preferably 100,000 or greater, particularly preferably 200,000 or greater. If the viscosity index improver has a weight average molecular weight of less than 10,000, it would be less

effective in viscosity index enhancement when it is dissolved in the lubricating base oil and the resulting composition would not only be poor in fuel saving properties and low temperature viscosity characteristics but also be high in production cost. If the viscosity index improver has a weight-average molecular weight of greater than 400,000, it would exert the viscosity increasing effect too much and thus the resulting composition would not only be poor in fuel saving properties and low temperature viscosity characteristics but also be degraded in shear stability, solubility in the lubricating base oil and storage stability.

[0065] The viscosity index improver used in the present invention has a PSSI (permanent shear stability index) of necessarily 20 or less, more preferably 17 or less, more preferably 16 or less, particularly preferably 15 or less. If the PSSI exceeds 20, the resulting composition would be degraded in shear stability and thus needed to be enhanced in initial kinematic viscosity, possibly resulting in degraded fuel saving properties. If the PSSI is less than 1, the viscosity index improver would be less effective in viscosity index enhancement when it is dissolved in the lubricating base oil and thus the resulting

composition would not only be poor fuel saving properties and low temperature viscosity characteristics but also increased in production cost. The PSSI is, therefore, preferably 1 or greater.

[0066] The ratio of the weight-average molecular weight and PSSI (MW/PSSI) of the viscosity index improver used in the present invention is preferably 1.0×10^4 or greater, more preferably 1.5×10^4 or greater, more preferably 2.0×10^4 or greater. If the MW/PSSI is less than 1.0×10^4 , the resulting composition would be degraded in fuel saving properties and low temperature startability, i.e., viscosity temperature characteristics and low temperature viscosity characteristics.

[0067] The ratio of the weight-average molecular weight (M_w) and number average molecular weight (M_n) (M_w/M_n) of the viscosity index improver used in the present invention is preferably 5.0 or less, more preferably 4.0 or less, more preferably 3.5 or less, particularly preferably 3.0 or less. The M_w/M_n is preferably 1.0 or greater, more preferably 2.0 or greater, more preferably 2.5 or greater, particularly preferably 2.6 or greater. If the M_w/M_n exceeds 5.0 or less than 1.0, the viscosity index improver would be degraded in solubility and viscosity temperature

characteristics improving effect and thus the resulting composition would not maintain sufficient storage stability or fuel saving properties.

[0068] The content of the viscosity index improver in the lubricating oil composition of the present invention is preferably from 0.1 to 50 percent by mass, preferably from 0.5 to 20 percent by mass, more preferably from 1.0 to 15 percent by mass, more preferably from 1.5 to 12 percent by mass on the basis of the total mass of the composition. If the content is less than 0.1 percent by mass, the resulting composition would be insufficient in low temperature characteristics. If the content exceeds 50 percent by mass, the resulting composition would be degraded in shear stability.

[0069] The lubricating oil composition of the present invention comprises (B) an overbasic metallic detergent with a metal ratio of 3.4 or less. Whereby, the lubricating oil composition of the present invention can be enhanced in fuel saving properties compared with a composition not containing such a metallic detergent.

[0070] Component (B), i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the present invention may be an overbasic compound of an

oil-soluble metal salt of a compound having an OH group and/or a carbonyl group. Alternatively, the overbasic metallic detergent may be an overbasic metal salt that may be produced by reacting an overbasic metal salt such as an alkaline earth metal sulfonate, an alkaline earth metal carboxylate, an alkaline earth metal salicylate, an alkaline earth metal phenate or an alkaline earth metal phosphonate, an alkaline earth metal hydroxide or oxide and boric acid or boric anhydride. Examples of the alkaline earth metal include magnesium, calcium and barium. Preferred is calcium. The overbasic metal salt is preferably an overbasic compound of an oil-soluble metal salt of an OH group and/or carbonyl group-containing hydrocarbon compound, more preferably an oil-soluble metal salt of an OH group and/or carbonyl group-containing hydrocarbon compound overbased with an alkaline earth metal borate. Alkaline earth metal salicylates are preferably used while alkaline earth metal salicylates overbased with an alkaline earth metal borate are more preferably used.

[0071] Component (B), i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the present invention has a base number of preferably 50 mgKOH/g or greater, more preferably 100 mgKOH/g or

greater, more preferably 120 mgKOH/g or greater, particularly preferably 140 mgKOH/g or greater, most preferably 150 mgKOH/g or greater. Component (B) has a base number of preferably 300 mgKOH/g or less, more preferably 200 mgKOH/g or less, more preferably 180 mgKOH/g or less, particularly preferably 170 mgKOH/g or less. If the base number is less than 50 mgKOH/g, the resulting composition would be degraded in fuel saving properties as the viscosity increases and likely be insufficient in friction reducing effect by addition of the metallic detergent. If the base number exceeds 300 mgKOH/g, the metallic detergent would likely inhibit the effect of an anti-wear additive and a friction reducing effect would be insufficient. The term "base number" used herein denotes the value measured by JIS K 2501 5.2.3.

[0072] Component (B), i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the present invention has a particle diameter of preferably 0.1 μm or smaller, more preferably 0.05 μm or smaller.

[0073] Any method may be used to produce Component (B), i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the present invention. For example, the above-described oil-soluble metal salt, alkaline earth metal hydroxide or oxide and boric

acid or boric anhydride are reacted in the presence of water, alcohol such as methanol, ethanol, propanol or butanol and a dilution solvent such as benzene, toluene or xylene at a temperature of 20 to 200°C for 2 to 8 hours, and then heated to a temperature of 100 to 200°C, followed by removal of water and if necessary the alcohol and dilution solvent thereby producing Component (B). These detailed reaction conditions are arbitrarily selected depending on the amounts of the raw material and the reaction product. The details of the method are described in for example Japanese Patent Application Laid-Open Publication Nos. 60-116688 and 61-204298. The oil-soluble metal salt overbased with an alkaline earth metal borate produced by the above-described method has a particle diameter of usually 0.1 μm or smaller and a total base number of usually 100 mgKOH/g or greater and thus can be used preferably in the lubricating oil composition of the present invention.

[0074] Component (B), i.e., the overbasic metallic detergent used in the present invention has necessarily a metal ratio of 3.4 or less.

The metallic detergent is adjusted to have a metal ratio of preferably 3.2 or less, more preferably 3.0 or less, more preferably 2.8 or less, particularly

preferably 2.6 or less, most preferably 2.5 or less. If the metal ratio exceeds 3.4, the resulting composition would be insufficient in friction torque reduction, i.e., fuel saving properties would be.

The metallic detergent is adjusted to have a metal ratio of preferably 1.0 or greater, more preferably 1.1 or greater, more preferably 1.5 or greater, particularly preferably 1.9 or greater, most preferably 2.2 or greater. This is because if the metal ratio is less than 1.0, the resulting internal combustion engine lubricating oil composition would be high in kinematic viscosity and low temperature viscosity and thus would cause problems with lubricity or startability.

A solely synthesized metallic detergent is preferably used in order to obtain a higher friction reducing effect.

[0075] The term "metal ratio" used herein is represented by $(\text{valence of metal element in a salicylate detergent}) \times (\text{metal element content (mole\%)}) / (\text{soap group content (mole\%)})$. The metal element denotes calcium and magnesium. The soap group denotes sulfonic acid, phenol and salicylic acid groups.

[0076] The alkyl or alkenyl group of Component (B),

i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the present is an alkyl or alkenyl group having 8 or more, preferably 10 or more, more preferably 12 or more and 19 or fewer carbon atoms. If Component (B) has an alkyl or alkenyl group having fewer than 8 carbon atoms, it would be insufficient in oil solubility.

[0077] The alkyl or alkenyl group may be straight-chain or branched but is preferably straight-chain. The alkyl or alkenyl group may be a primary alkyl or alkenyl group, a secondary alkyl or alkenyl group or a tertiary alkyl or alkenyl group, but for the secondary alkyl or alkenyl group or tertiary alkyl or alkenyl group, the position of the branch is preferably only at the carbon bonding to an aromatic.

[0078] The content of Component (B), i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the lubricating oil composition of the present invention is preferably from 0.01 to 30 percent by mass, more preferably from 0.05 to 5 percent by mass, on the basis of the total mass of the lubricating oil composition. If the content is less than 0.01 percent by mass, the fuel saving effect would last only for a short period of time. If the content exceeds 30 percent by mass, an advantageous effect as balanced with the

content would not be obtained.

[0079] The content of Component (B), i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the lubricating oil composition of the present invention is preferably 0.01 percent by mass or more, more preferably 0.05 percent by mass or more, more preferably 0.10 percent by mass or more, particularly preferably 0.15 percent by mass or more and preferably 0.5 percent by mass or less, more preferably 0.4 percent by mass or less, more preferably 0.3 percent by mass or less, particularly preferably 0.25 percent by mass or less, most preferably 0.22 percent by mass or less on the metal basis of the total mass of the lubricating oil composition. If the content is less than 0.01 percent by mass, the friction reducing effect achieved by addition of the metal detergent would be likely insufficient and the resulting lubricating oil composition would be likely insufficient in fuel saving properties, thermal/oxidation stability and detergency. Whilst, the content exceeds 0.5 percent by mass, the friction reducing effect achieved by addition of the metal detergent would be likely insufficient and the resulting lubricating oil composition would be likely insufficient in fuel saving properties.

[0080] The content of Component (B), i.e., the overbasic metallic detergent with a metal ratio of 3.4 or less used in the lubricating oil composition of the present invention is preferably 0.01 percent by mass or more, more preferably 0.03 percent by mass or more, more preferably 0.04 percent by mass or more, particularly preferably 0.05 percent by mass or more and preferably 0.20 percent by mass or less, more preferably 0.10 percent by mass or less, more preferably 0.08 percent by mass or less, particularly preferably 0.07 percent by mass or less, most preferably 0.06 percent by mass or less on the boron basis of the total mass of the lubricating oil composition. If the content is less than 0.01 percent by mass, the friction reducing effect achieved by addition of the metal detergent would be likely insufficient and the resulting lubricating oil composition would be likely insufficient in fuel saving properties, thermal/oxidation stability and detergency. Whilst, if the content exceeds 0.2 percent by mass, the friction reducing effect achieved by addition of the metal detergent would be likely insufficient and the resulting lubricating oil composition would be likely insufficient in fuel saving properties.

[0081] The ratio $(MB1)/(MB2)$ of the content of metal derived from Component (B) (MB1) and the content of boron derived from Component (B) (MB2) in the lubricating oil composition of the present invention is preferably 1 or greater, more preferably 2 or greater, more preferably 2.5 or greater, particularly preferably 3.0 or greater, most preferably 3.5 or greater. If the $(MB1)/(MB2)$ is less than 1, the fuel saving properties would be possibly degraded. The $(MB1)/(MB2)$ is preferably 20 or less, more preferably 15 or less, more preferably 10 or less, particularly preferably 5 or less. If the $(MB1)/(MB2)$ exceeds 20, the fuel saving properties would be possibly degraded.

[0082] The lubricating oil composition of the present invention comprises (C) a friction modifier. Whereby, the lubricating oil composition of the present invention can be enhanced in fuel saving properties compared with a composition not containing such a friction modifier. Examples of Component (C), i.e., the friction modifier include one or more types of friction modifiers selected from organic molybdenum compounds and ashless friction modifiers.

[0083] Examples of the organic molybdenum compound include sulfur-containing organic molybdenum compounds such as molybdenum dithiophosphate and

molybdenum dithiocarbamate; complexes of molybdenum compounds (for example, molybdenum oxides such as molybdenum dioxide and molybdenum trioxide, molybdic acids such as orthomolybdic acid, paramolybdic acid, and sulfurized (poly)molybdic acid, metal salts of these molybdic acids, molybdic acid salts such as ammonium salts of these molybdic acids, molybdenum sulfides such as molybdenum disulfide, molybdenum trisulfide, molybdenum pentasulfide, and molybdenum polysulfide, sulfurized molybdenum acid, metal and amine salts of sulfurized molybdenum acid, and halogenated molybdenum such as molybdenum chloride) and sulfur-containing organic compounds (for example, alkyl(thio)xanthate, thiaziazole, mercaptothiadiazole, thiocarbonate, tetrahydrocarbylthiuramdisulfide, bis(di(thio)hydrocarbyldithiophosphonate)disulfide, organic (poly)sulfide, and sulfurized esters) or other organic compounds; complexes of sulfur-containing molybdenum compounds such as the above-mentioned molybdenum sulfides and sulfurized molybdenum acid and alkenyl succinimide.

[0084] Alternatively, the organic molybdenum compound may be a sulfur-free molybdenum compound. Examples of such a molybdenum compound include

molybdenum-amine complexes, molybdenum-succinimide complexes, molybdenum salts of organic acids, and molybdenum salts of alcohols, among which preferred are molybdenum-amine complexes, molybdenum salts of organic acids, and molybdenum salts of alcohols.

[0085] No particular limitation is imposed on the content of the organic molybdenum compound if contained in the lubricating oil composition of the present invention, which is, however, preferably 0.001 percent by mass or more, more preferably 0.005 percent by mass or more, more preferably 0.01 percent by mass or more, particularly preferably 0.03 percent by mass or more and preferably 0.2 percent by mass or less, more preferably 0.1 percent by mass or less, more preferably 0.08 percent by mass or less, particularly preferably 0.06 percent by mass or less on the molybdenum basis of the total mass of the lubricating oil composition. If the content is less than 0.001 percent by mass, the friction reducing effect achieved by addition of the friction modifier would be likely insufficient and the resulting lubricating oil composition would be likely insufficient in fuel saving properties and thermal/oxidation stability. If the content exceeds 0.2 percent by mass, an advantageous effect as balanced with the content cannot be obtained, and the resulting

lubricating oil composition would tend to be degraded in storage stability.

[0086] The ashless friction modifier which may be used in the present invention may be any compound that is usually used as a friction modifier for lubricating oils. Examples of such an ashless friction modifier include compounds having 6 to 50 carbon atoms, containing one or more types of hetero elements selected from oxygen , nitrogen and sulfur per molecule. More specific examples include ashless friction modifiers such as amine compounds, fatty acid esters, fatty acid amides, fatty acids, aliphatic alcohols, aliphatic ethers, urea compounds, and hydrazide compounds, each having at least one alkyl or alkenyl group having 6 to 30 carbon atoms, in particular straight-chain alkyl, straight-chain alkenyl, branched alkyl or branched alkenyl group having 6 to 30 carbon atoms per molecule.

[0087] The content of the ashless friction modifier in the lubricating oil composition of the present invention is preferably 0.01 percent by mass or more, more preferably 0.1 percent by mass or more, more preferably 0.3 percent by mass or more and preferably 3 percent by mass or less, more preferably 2 percent by mass or less, more preferably 1 percent by mass or

less. If the content is less than 0.01 percent by mass, the friction reducing effect achieved by addition of the friction modifier would tend to be insufficient. If the content is more than 3 percent by mass, the ashless friction modifier would tend to inhibit anti-wear additives from exhibiting their effects or deteriorate the solubility thereof.

[0088] Component (C), i.e., the friction modifier used in the present invention is preferably an organic molybdenum friction modifier, more preferably a sulfur-containing organic molybdenum compound, more preferably molybdenum dithiocarbamate.

[0089] The lubricating oil composition of the present invention may be blended with any additives that have been generally used in a lubricating oil depending on the purposes in order to further enhance the properties. Examples of such additives include metallic detergents other than Component (B), ashless dispersants, antiwear agent (or extreme pressure additive), anti-oxidants, corrosion inhibitors, rust inhibitors, demulsifiers, metal deactivators, and anti-foaming agents.

[0090] Examples of the metallic detergents other than Component (B) include normal salt and/or basic salt such as alkali metal/alkaline earth metal

sulfonates, alkali metal/alkaline earth metal phenates, and alkali metal/alkaline earth metal salicylates. Examples of the alkali metal include sodium and potassium. Examples of the alkaline earth metal include magnesium, calcium and barium. Preferred are magnesium and calcium. Particularly preferred is calcium.

[0091] The ashless dispersant may be any ashless dispersant that is usually used for a lubricating oil. Examples of the ashless dispersant include mono- or bis-succinimides having in their molecules at least one straight-chain or branched alkyl or alkenyl group having 40 to 400 carbon atoms, benzylamines having in their molecules at least one alkyl or alkenyl group having 40 to 400 carbon atoms, polyamines having in their molecules at least one alkyl or alkenyl group having 40 to 400 carbon atoms, and boron-, carboxylic acid-, and phosphoric acid-modified products thereof. Any one or more of these ashless dispersants may be blended.

[0092] The anti-oxidant may be an ashless anti-oxidant such as a phenol- or amine-based anti-oxidant, or a metallic anti-oxidant such as a copper- or molybdenum-based anti-oxidant. Specific examples of the phenol-based anti-oxidant include

4,4'-methylene bis(2,6-di-tert-butylphenol) and 4,4'-bis(2,6-di-tert-butylphenol). Specific examples of the amine-based anti-oxidant include phenyl- α -naphthylamines, alkylphenyl- α -naphthylamines and dialkyldiphenylamines.

[0093] The antiwear agent (or extreme pressure additive) may be any anti-oxidant or extreme pressure additive that has been used for lubricating oil. For example, sulfuric-, phosphoric- and sulfuric-phosphoric extreme pressure additives may be used. Specific examples include phosphorus acid esters, thiophosphorus acid esters, dithiophosphorus acid esters, trithiophosphorus acid esters, phosphoric acid esters, thiophosphoric acid esters, dithiophosphoric acid esters, trithiophosphoric acid esters, amine salts, metal salts or derivatives thereof, dithiocarbamates, zinc dithiocarbamates, molybdenum dithiocarbamates, disulfides, polysulfides, and sulfurized fats and oils. Among these antiwear agents, preferred are sulfuric extreme pressure additives, and particularly preferred are sulfurized fats and oils.

[0094] Examples of the corrosion inhibitor include benzotriazole-, tolyltriazole-, thiadiazole-, and imidazole-types compounds.

[0095] Examples of the rust inhibitor include petroleum sulfonates, alkylbenzene sulfonates, dinonylnaphthalene sulfonates, alkenyl succinic acid esters, and polyhydric alcohol esters.

[0096] Examples of the demulsifier include polyalkylene glycol-based non-ionic surfactants such as polyoxyethylenealkyl ethers, polyoxyethylenealkylphenyl ethers, and polyoxyethylenealkylnaphthyl ethers.

[0097] Examples of the metal deactivator include imidazolines, pyrimidine derivatives, alkylthiadiazoles, mercaptobenzothiazoles, benzotriazoles and derivatives thereof, 1,3,4-thiadiazolepolysulfide, 1,3,4-thiadiazolyl-2,5-bisdialkyldithiocarbamate, 2-(alkyldithio)benzoimidazole, and β -(o-carboxybenzylthio)propionitrile.

[0098] Examples of the anti-foaming agent include silicone oil with a 25°C kinematic viscosity of 1,000 to 100,000 mm²/s, alkenylsuccinic acid derivatives, esters of polyhydroxy aliphatic alcohols and long-chain fatty acids, aromatic amine salts of methylsalicylate and o-hydroxybenzyl alcohol.

[0099] When these additives are contained in the lubricating oil composition of the present invention,

they are contained in an amount of 0.01 to 10 percent by mass on the total composition mass basis.

[0100] The 100°C kinematic viscosity of the lubricating oil composition of the present invention is preferably 4 to 12 mm²/s, more preferably 9.0 mm²/s or lower, more preferably 8.0 mm²/s or lower, more preferably 7.0 mm²/s or lower, particularly preferably 6.8 mm²/s or lower. The 100°C kinematic viscosity of the lubricating oil composition of the present invention is preferably 4.5 mm²/s or higher, more preferably 5.0 mm²/s or higher, more preferably 5.5 mm²/s or higher, particularly preferably 6.0 mm²/s or higher. The 100°C kinematic viscosity referred herein denotes the viscosity at 100°C defined by ASTM D-445. If the 100°C kinematic viscosity is lower than 4 mm²/s, the resulting lubricating oil composition would lack lubricity. If the 100°C kinematic viscosity exceeds 12 mm²/s, the resulting composition would not obtain the required low temperature viscosity characteristics and sufficient fuel saving properties.

[0101] The 40°C kinematic viscosity of the lubricating oil composition in the present invention is preferably from 4 to 50 mm²/s, preferably 40 mm²/s or lower, more preferably 35 mm²/s or lower, particularly preferably 30 mm²/s or lower, most

preferably $27 \text{ mm}^2/\text{s}$ or lower. The 40°C kinematic viscosity of the lubricating oil composition of the present invention is preferably $15 \text{ mm}^2/\text{s}$ or higher, more preferably $18 \text{ mm}^2/\text{s}$ or higher, more preferably $20 \text{ mm}^2/\text{s}$ or higher, particularly preferably $22 \text{ mm}^2/\text{s}$ or higher. The 40°C kinematic viscosity referred herein denotes the viscosity at 40°C defined by ASTM D-445. If the 40°C kinematic viscosity is lower than $4 \text{ mm}^2/\text{s}$, the resulting lubricating oil composition would lack lubricity. If the 100°C kinematic viscosity exceeds $50 \text{ mm}^2/\text{s}$, the resulting composition would not obtain the required low temperature viscosity and sufficient fuel saving properties.

[0102] The viscosity index of the lubricating oil composition of the present invention is preferably within the range of 140 to 400, more preferably 190 or greater, more preferably 200 or greater, more preferably 210 or greater, particularly preferably 220 or greater, most preferably 230 or greater. If the lubricating oil composition of the present invention has a viscosity index of less than 140, it would be difficult to improve the fuel saving properties while maintaining the 150°C HTHS viscosity and reduce the low temperature viscosity at -35°C . If the viscosity index of the lubricating oil composition of the present

invention is greater than 400, the resulting composition would be degraded in evaporability and cause malfunctions caused by the lack of solubility of additives and the incompatibility with seal materials.

[0103] The 100°C HTHS viscosity of the lubricating oil composition of the present invention is preferably 5.2 mPa·s or lower, more preferably 5.0 mPa·s or lower, more preferably 4.7 mPa·s or lower, particularly preferably 4.5 mPa·s or lower. Whilst, the 100°C HTHS viscosity is preferably 3.0 mPa·s or higher, more preferably 3.5 mPa·s or higher, particularly preferably 4.0 mPa·s or higher, most preferably 4.1 mPa·s or higher. The 100°C HTHS viscosity referred herein denotes the high temperature high shear viscosity at 100°C defined in accordance with ASTM D4683. If the 100°C HTHS viscosity is lower than 3.0 mPa·s, the resulting composition would lack lubricity. If the HTHS viscosity exceeds 5.2 mPa·s, the resulting composition would not obtain the required low temperature viscosity and sufficient fuel saving properties.

[0104] The 150°C HTHS viscosity of the lubricating oil composition of the present invention is lower than 2.6 mPa·s but is more preferably 2.5 mPa·s or lower, more preferably 2.45 mPa·s or lower, particularly

preferably 2.4 mPa·s or lower and preferably 2.0 mPa·s or higher, more preferably 2.1 mPa·s or higher, more preferably 2.2 mPa·s or higher, particularly preferably 2.3 mPa·s or higher. The 150°C HTHS viscosity referred herein denotes the high temperature high shear viscosity at 150°C defined in accordance with ASTM D4683. If the 150°C HTHS viscosity is lower than 2.0 mPa·s, the resulting composition would lack lubricity. If the 150°C HTHS viscosity is 2.6 mPa·s or higher, the resulting composition would not obtain sufficient fuel saving properties.

[0105] The ratio of the 150°C HTHS viscosity and 100°C HTHS viscosity (150°C HTHS viscosity/100°C HTHS viscosity) in the lubricating oil composition of the present invention is preferably 0.50 or greater, more preferably 0.52 or greater, more preferably 0.54, particularly preferably 0.55 or greater, most preferably 0.56 or greater. If the ratio is less than 0.50, the resulting composition would not obtain the required low temperature viscosity or sufficient fuel saving properties.

[0106] The lubricating oil composition of the present invention is a lubricating oil composition that is an engine oil having a 150°C HTHS viscosity of lower than 2.6 mPa·s, can reduce sufficiently the 40°C

kinematic viscosity, 100°C kinematic viscosity and 100°C HTHS viscosity and suppress the friction coefficient of a boundary lubrication region from increasing and has excellent fuel saving properties. The lubricating oil composition of the present invention having such excellent properties can be suitably used as a fuel saving engine oil such as a fuel saving gasoline engine oil or a fuel saving diesel engine oil.

Examples

[0107] The present invention will be described in more detail below with reference to the following Examples and Comparative Examples but are not limited thereto.

[0108] (Examples 1 to 5, Comparative Examples 1 to 4)

In Examples 1 to 5 and Comparative Examples 1 to 4, lubricating oil compositions having formulations set forth in Table 2 below were prepared using the following base oils and additives. Table 1 sets forth the properties of base oils O-1, O-2 and O-3.

(Base Oils)

O-1 (base oil 1): mineral oil produced by hydrocracking/hydroisomerizing a n-paraffin-containing oil

O-2 (base oil 2): hydrocracked mineral oil

O-3 (base oil 3): hydrocracked mineral oil

(Additive)

A-1: non-dispersant type PMA viscosity index improver (Mw=360,000, PSSI=15, Mw/PSSI= 2.4×10^4)

A-2: non-dispersant type PMA viscosity index improver (Mw=330,000, PSSI=15, Mw/PSSI= 2.2×10^4)

a-1: non-dispersant type PMA viscosity index improver (Mw=380,000, PSSI=27, Mw/PSSI= 1.4×10^4)

a-2: dispersant type PMA viscosity index improver (Mw=400,000, PSSI=45, Mw/PSSI= 0.88×10^4)

B-1: overbasic boric acid calcium salicylate A (metal ratio 2.0, base number 139 mgKOH/g, Ca content 4.9 percent by mass, B content 1.3 percent by mass, Ca/B ratio 3.8, alkyl group chain length 14 to 18)

B-2: overbasic boric acid calcium salicylate B (metal ratio 2.5, base number 158 mgKOH/g, Ca content 5.6 percent by mass, B content 1.7 percent by mass, Ca/B ratio 3.3, alkyl group chain length 14 to 18)

b-1: overbasic boric acid calcium salicylate C (metal ratio 3.5, base number 192 mgKOH/g, Ca content 6.8 percent by mass, B content 2.7 percent by mass, Ca/B ratio 2.5, alkyl group chain length 14 to 18)

C-1: MoDTC (alkyl group chain length C8/C13,

Mo content 10 percent by mass, sulfur content 11 percent by mass)

d-1: succinimide dispersant (Mw 13,000, alkyl group chain length 1900, nitrogen content 0.6 percent by mass)

e-1: ZnDTP (alkyl group chain length C4/C6, secondary, Zn content 7.8 percent by mass, P content 7.2 percent by mass, S content 15.0 percent by mass)

f-1: other additives (anti-oxidant, antiwear agent, pour point depressants, anti-foaming agents)

[0109]

		O-1	O-2	O-3
		Base oil 1	Base oil 2	Base oil 3
Density (15°C)	g/cm ³	0.820	0.835	0.8320
Kinematic viscosity (40°C)	mm ² /s	15.8	20.0	13.5
(100°C)	mm ² /s	3.85	4.29	3.27
Viscosity index		141	123	112
Pour point	°C	-22.5	-17.5	-22.5
Aniline point	°C	119	116	109
Iodine number		0.06	0.05	5.38
Sulfur content	mass ppm	<1	<1	<1
Nitrogen content	mass ppm	<3	<3	<3
n-d-M analysis	%CP	93.3	80.7	72.6
	%CN	6.7	19.3	23.4
	%CA	0	0	0
Chromatographic fractionation	Saturate content	99.6	99.7	99.6
mass%	Aromatic content	0.2	0.2	0.3
	Resin content	0.1	0.1	0.1
	Recovery rate	99.9	100	100
Paraffin content based on	mass%	87.1	53.8	50.7
saturate content				
Naphthene content based on	mass%	12.9	46.2	49.3
saturate content				

[0110] [Evaluation of lubricating oil compositions]

The 40°C and 100°C kinematic viscosities, viscosity index, and 100°C and 150°C HTHS viscosities were measured for each of the lubricating oil compositions of Examples 1 to 5 and Comparative Examples 1 to 4. The fuel saving properties were evaluated by measuring the friction torque at a driving valve system. Each physical properties and fuel saving properties were measured in the following evaluation method. The results are set forth in Table 2 below.

(1) kinematic viscosity: ASTM D-445

(2) viscosity index: JIS K 2283-1993

(3) HTHS viscosity: ASTM D-4683

(4) Driving valve system motoring friction test: the friction torques at an oil temperature of 100°C and a revolution number 350 rpm was measured using an apparatus that can measure the friction torque at a pair of cam and tappet of the driving valve system in a direct strike-type four-cylinder engine. The rate of improvement of each composition was calculated based on the friction torque of Comparative Example 1.

[0111]

Base oil	Base oil total mass basis		Example 1	Example 2	Example 3	Example 4	Example 5	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4
O-1	Base oil 1	mass%	50	50							
O-2	Base oil 2	mass%			50	50	100	50	50	50	50
O-3	Base oil 3	mass%	50	50	50	50		50	50	50	50
	Base oil viscosity (40°C)	mm ² /s	14.7	14.7	16.2	16.2	19.8	16.2	16.2	16.2	16.2
	Base oil viscosity (100°C)		3.6	3.6	3.7	3.7	4.3	3.7	3.7	3.7	3.7
	Base oil viscosity index		124	124	117	117	122	117	117	117	117
Additives	Composition total mass basis										
A-1	Viscosity index improver 1	mass%	9.9	12.4	10.6		10.2	10.9			10.9
A-2	Viscosity index improver 2	mass%				10.8					
a-1	Viscosity index improver 3	mass%							13.3		
a-2	Viscosity index improver 3	mass%								5.1	
B-1	Overbasic metallic detergent 1	mass%	4.06								
B-2	Overbasic metallic detergent 2	mass%		3.57	3.57	3.57	3.57				3.57
b-1	Overbasic metallic detergent 3	mass%						2.94	2.94	2.94	
C-1	MoDTC	mass%	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	
d-1	Succinimide	mass%	5	5	5	5	5	5	5	5	5
e-1	ZnDTP	mass%	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
f-1	Other additives	mass%	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Evaluation results											
Kinematic viscosity	40°C	mm ² /s	26.3	24.9	26.9	27.6	30.4	26.3	28.8	34.6	25.9
	100°C	mm ² /s	6.7	6.7	6.7	6.8	6.9	6.6	7.3	8.1	6.6
Viscosity index			231	249	224	219	198	224	235	222	229
HTHS viscosity	100°C	mPa·s	4.3	4.2	4.3	4.4	4.7	4.3	4.3	4.9	4.3
	150°C	mPa·s	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
HTHS viscosity (150°C)/HTHS viscosity (100°C)			0.56	0.57	0.56	0.55	0.51	0.56	0.56	0.49	0.56
Motoring friction improved rate			%	7.9	4.4	4.3	4.3	4.0	0.0	0.0	-14.0

[0112] As set forth in Table 2, the lubricating oil compositions of Examples 1 to 5 containing all of Components (A) to (C) are higher in rate of friction improvement in the driving valve system motoring friction test and more excellent in fuel saving properties compared with the lubricating oil compositions of Comparative Examples 1 to 4 having a comparable level of 150°C HTHS viscosity and containing no Component (B) or Component (C). It is appreciated that the lubricating oil compositions of Comparative Examples 1 to 3 containing Component (B) with a metal ratio of greater than 3.4 are significantly poorer in rate of friction improvement in the driving valve system motoring friction test while the lubricating oil compositions of Comparative Examples 2 and 3 containing a viscosity index improver with a PSSI of greater than 20 as Component (A) are higher in kinematic viscosities and significantly poorer in fuel saving properties. The lubricating oil composition of Comparative Example 4 containing no Component (C) is significantly poorer in the friction improving rate.

CLAIMS

[Claim 1] A lubricating oil composition
comprising:

 a lubricating base oil with a 100°C kinematic
viscosity of 1 to 5 mm²/s;

 (A) a viscosity index improver with a weight
average molecular weight of 400,000 or less and a PSSI
of 20 or less;

 (B) an overbasic metallic detergent with a metal
ratio of 3.4 or less; and

 (C) a friction modifier,
and having a 150°C HTHS viscosity of lower than 2.6 mPa·
s.

[Claim 2] The lubricating oil composition
according to claim 1, wherein the viscosity index
improver is a viscosity index improver with a ratio of
the weight-average molecular weight and PSSI (Mw/PSSI)
of 1×10^4 or greater.

[Claim 3] The lubricating oil composition
according to claim 1 or 2, wherein the overbasic
metallic detergent is an overbasic alkaline earth metal
salicylate produced by overbasing an alkaline earth
metal salicylate with an alkaline earth metal borate.

[Claim 4] The lubricating oil composition

according to any of claims 1 to 3, wherein the friction modifier is preferably an organic molybdenum friction modifier.