LUBRICATING OIL COMPOSITION FOR INTERNAL-COMBUSTION ENGINE, AND METHOD FOR REDUCING FRICTION IN GASOLINE ENGINE

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Appl. No.: 15/559,579

PCT Filed: Mar. 9, 2016

PCT No.: PCT/JP2016/057465

§ 371 (c)(1), (2) Date: Sep. 19, 2017

Foreign Application Priority Data
Mar. 23, 2015 (JP) ................................. 2015-059666

Provided is a lubricating oil composition for internal combustion engines capable of exhibit a sufficient friction-reducing effect from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher. The lubricating oil composition for internal combustion engines contains a surfactant having an alkylene oxide as the constituent unit and having an HLB value of 7 or more and less than 15, and a lubricant base oil.
LUBRICATING OIL COMPOSITION FOR INTERNAL-COMBUSTION ENGINE, AND METHOD FOR REDUCING FRICTION IN GASOLINE ENGINE

TECHNICAL FIELD

[0001] The present invention relates to a lubricating oil composition for an internal combustion engine.

BACKGROUND ART

[0002] Recently, for reducing energy loss and carbon dioxide emission in driving automobiles, development of fuel-saving performance of automobiles is under investigation. As a means for improving fuel-saving performance of automobiles, car body weight reduction is now under way, but lubricating oil is also desired to contribute toward fuel-saving performance. Consequently, improvement of further friction reduction by lubricating oil is being investigated.

[0003] Methods for friction reduction by lubricating oil have been proposed in PTLs 1 to 5.

[0004] PTL 1 proposes use of a molybdenum compound such as MoDTC that is a typical one as a method for friction reduction, as a friction reducer.

[0005] PTLs 2 and 3 propose use of a boron-containing compound prepared by heating and stirring an organic compound having a hydroxyl group and an amino group, and a boric acid or a boric acid derivative in a high-temperature environment, as a friction reducer.

[0006] PTL 4 proposes a lubricating oil composition prepared by blending a nonionic surfactant having an HLB value of 15 or more, into a lubricant base oil.

[0007] PTL 5 proposes a lubricating oil composition for use in a friction-type driving force transmitting device, containing a specific amine compound.

CITATION LIST

Patent Literature

[0008] PTL 1: JP 2015-010177 A
[0012] PTL 5: WO2011/062282

DISCLOSURE OF INVENTION

Technical Problem

[0013] Herefore, regarding the fuel-saving performance of engine oil, the fuel economy performance mainly in a temperature range of 80 to 100°C or so is generally targeted, assuming after the end of warming-up operation of engines. Recently, however, fuel-saving performance in a low-temperature range of 25 to 60°C or so has become required, assuming at a time of engine starting.

[0014] However, mere addition of a molybdenum-based friction reducer as in PTL 1 could not realize a friction-reducing effect in a low-temperature range at a time of engine starting or the like, and therefore fuel-saving performance could not be sufficiently improved.

[0015] The friction reducer and the lubricating oil composition proposed in PTLs 2 to 5 are silent in friction reduction in a low-temperature range.

[0016] On the other hand, as a method of realizing a friction-reducing effect in a low temperature range, heretofore, an ash-free friction reducer such as a glycerin monooleate or the like has been used. However, such an ash-free friction reducer could not exhibit a friction-reducing effect in a practical temperature range of 80°C or higher.

[0017] At present, a lubricating oil composition for internal combustion engines is required to have a high friction-reducing effect from a low-temperature range at engine starting to a practical temperature range of 80°C or higher, and to have a low-ash content. Merely combining a molybdenum-based friction reducer and an ash-free friction reducer could hardly satisfy the requirements.

[0018] Given the situation, a lubricating oil composition using an ash-free friction reducer that can realize a sufficient friction-reducing effect from a low-temperature range at engine starting to even a practical temperature range of 80°C or higher is desired.

[0019] An object of the present invention is to provide a lubricating oil composition for internal combustion engines that can realize a sufficient friction-reducing effect not only in a low-temperature range assuming engine starting but also in a practical temperature range of 80°C or higher.

Solution to Problem

[0020] For solving the above-mentioned problems, an aspect of the present invention provides a lubricating oil composition for internal combustion engines, which contains a surfactant having an alkylene oxide as the constituent unit and having an HLB value of 7 or more and less than 15, and a lubricant base oil.

Advantageous Effects of Invention

[0021] The lubricating oil composition for internal combustion engines of the present invention can better a friction-reducing effect from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher, and eventually can better fuel-saving performance.

DESCRIPTION OF EMBODIMENTS

[0022] Embodiments of the present invention are described below.

[Lubricating Oil Composition for Internal Combustion Engine]

[0023] The lubricating oil composition for internal combustion engines of this embodiment contains a surfactant having an alkylene oxide as the constituent unit and having an HLB value of 7 or more and less than 15, and a lubricant base oil.

<Surfactant>

[0024] The lubricating oil composition for internal combustion engines of this embodiment contains a surfactant having an alkylene oxide as the constituent unit and having an HLB value of 7 or more and less than 15.

[0025] A surfactant having an HLB value falling within the above range but not having an alkylene oxide as the constituent unit tends to result in insufficient friction reduction. A surfactant having an alkylene oxide as the constituent unit but having an HLB value of less than 7 poorly adsorbs to a metal surface and is therefore poor in friction reduction. A surfactant having an alkylene oxide as the constituent unit but having an HLB value of more than 15 poorly dissolves in a lubricant base oil and is therefore extremely difficult to use.

[0026] As the above surfactant, various kinds of surfactants can be used, but from the viewpoint of friction reduction owing to adsorption to metal surfaces, an amine compound, an amide compound and the like in which an
alkylene oxide bonds to the nitrogen atom are preferred. Among these, an amine compound is preferred, and among amine compounds, a tertiary amine is preferred.

[0027] The surfactant of a tertiary amine compound includes compounds represented by the following general formula (I). The compounds represented by the general formula (I) are favorable in the point that the compounds have the above-mentioned effect and the ash content therein is 0% by mass:

$$R^1 \overset{\text{N}}{\text{A(O)}_{n_1}} \overset{\text{H}}{\text{A(O)}_{n_2}}$$

wherein $R^1$ and $R^2$ each independently represent an alkyl group having 4 to 18 carbon atoms, or an alkenyl group having 4 to 18 carbon atoms, wherein $x$ represents 0 or 1, when $x=0$, $y=1$, and when $x=1$, $y=0$, wherein $A^{O}$ and $A^{N}$ each independently represent an oxalkylene group having 2 to 4 carbon atoms, and wherein $n_1$ and $n_2$ each indicate an average addition molar number of the oxalkylene group, and each independently represent an integer of 1 to 13, and $n_1+n_2$ is 5 to 14.

[0028] The alkyl group and the alkenyl group for $R^1$ and $R^2$ may be linear, branched or cyclic, but is preferably linear. $R^1$ and $R^2$ each are preferably an alkyl group. When $x=0$, the alkyl group and the alkenyl group for $R^1$ each preferably have 12 to 18 carbon atoms. When $x=1$, the alkyl group and the alkenyl group for $R^1$ and $R^2$ each preferably have 4 to 16 carbon atoms.

[0029] The oxalkylene group for $A^{O}$ and $A^{N}$ preferably has 2 to 3 carbon atoms, more preferably 2 carbon atoms.

[0030] Preferably, $n_1$ and $n_2$ each independently represent an integer of 2 to 10, more preferably 3 to 7. $n_1+n_2$ is preferably 8 to 12, more preferably 9 to 11.

[0031] Regarding (A0)$_{n_1}$ and (A0)$_{n_2}$ oxalkylene groups having a different number of carbon atoms may bond to each other randomly or in blocks. For example, (A0)$_{n_1}$ and (A0)$_{n_2}$ may be those of ethylene oxide (EO) groups and propylene oxide (PO) groups bonding to each other randomly or in blocks.

[0032] In the case where a tertiary amine of the general formula (I) is used as the surfactant, those of the same kind or those of different kinds as combined may be used. The same kind means that $R^1$, $R^2$ and others in the above general formula (I) are all the same. Different kinds mean that one or more of $R^1$, $R^2$ and others in the above general formula (I) differs from each other.

[0033] In the case where different kinds are mixed, it is desirable that they contain large quantities of preferred embodiments. For example, the proportion of the mass of the tertiary amine of the general formula (I) where $R^1$ and $R^2$ each an alkyl group or an alkenyl group to the total mass of the tertiary amine [mass of the tertiary amine of the general formula (I) where $R^1$ and $R^2$ each an alkyl group/total mass of the tertiary amine of the general formula (I)] is preferably 60% by mass or more, more preferably 70% by mass or more, even more preferably 80% by mass or more.

[0034] From the viewpoint of stability of the effect, tertiary amines of the general formula (I) where $R^2$ all has the same number of carbon atoms are preferably used. In the case where the tertiary amine of the general formula (I) contains $R^2$, those where additionally $R^2$ all has the same number of carbon atoms are preferably used.

[0035] As the surfactant, a polyoxyalkylene fatty acid ester is also preferred.

[0036] The number of carbon atoms constituting the oxalkylene group of the polyoxyalkylene fatty acid ester is preferably 2 to 4, more preferably 2 to 3, even more preferably 2. Regarding the bonding mode of the oxalkylene group, oxalkylene groups differ in point of the number of constituent carbon atoms may bond to each other randomly or in blocks. Preferably, the average addition molar number of the oxalkylene groups is an integer of 2 to 10, more preferably 3 to 7.

[0037] The number of carbon atoms constituting the constituent unit derived from the fatty acid of the polyoxyalkylene fatty acid ester is preferably 8 to 28, more preferably 14 to 22, even more preferably 16 to 20.

[0038] The polyoxyalkylene fatty acid ester of the type includes a polyoxyethylene oleate, a polyoxyethylene stearate, etc.

[0039] The molecular weight of the above-mentioned surfactant is, from the viewpoint of reducing friction and making friction reducing agents consist with detergency, preferably in a range of 350 to 950 g/mol, more preferably in a range of 440 to 940 g/mol.

[0040] In this embodiment, the molecular weight of the surfactant is one measured on a mass spectrum according to liquid chromatography mass spectrometry (LC/MS). Specifically, a range in which a peak of mass/charge ratio (m/z) of the surfactant appears is considered as a range of the molecular weight (g/mol) of the surfactant.

[0041] Also preferably, the surfactant contains 0% by mass of ash.

[0042] In this embodiment, the surfactant is contained in the lubricating oil composition for internal combustion engines preferably in an amount of 0.01 to 2.0% by mass, more preferably 0.1 to 1.5% by mass, even more preferably 0.2 to 1.0% by mass.

[0043] When the content of the surfactant is 0.01% by mass or more, friction can be reduced from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher. When the content of the surfactant is 2.0% by mass or less, reduction in detergency can be readily prevented from lowering while maintaining friction reduction.

<100-MODIFIED SUCINIMIDEE>

[0044] Preferably, the lubricating oil composition for internal combustion engines of this embodiment further contains a boron-modified succinimide.

[0045] Containing a boron-modified succinimide along with the above-mentioned surfactant, the composition can reduce friction more efficiently from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher and can make a deterioration of the composition good.

[0046] The boron-modified succinimide includes those prepared by boronating an alkaryl or alkylsuccinic acid monoimide or an alkaryl or alkylsuccinic acid bisimide.

[0047] The alkaryl or alkylsuccinic acid monoimide includes compounds represented by the following general formula (II). The alkaryl or alkylsuccinic acid bisimide includes compounds represented by the following general formula (III).
In the formulae (II) and (III), R³, R⁴ and R⁵ each represent an alkyl group or an alkenyl group, and the weight-average molecular weight thereof is preferably 500 to 3,000, more preferably 1,000 to 3,000.

When the weight-average molecular weight of R³, R⁴ and R⁵ is 500 or more, the solubility of the compound in a lubricant base oil is good. When 3,000 or less, the compound is expected to adequately exhibit the effect thereof. R³ and R⁶ can be the same or different.

R³, R⁴ and R⁵ each represent an alkenyl group having 2 to 5 carbon atoms, and R³ and R⁶ can be the same or different. n³ represents an integer of 1 to 10, n⁴ represents 0 or an integer of 1 to 10. Here, n³ is preferably 2 to 5, more preferably 2 to 4. When n³ is 2 or more, the compound is expected to exhibit more easily the effect of the boron-modified succinimide. When n³ is 5 or less, the solubility of the compound in a lubricant base oil is better.

In the general formula (III), n⁴ is preferably 1 to 6, more preferably 2 to 6. When n⁴ is 1 or more, the compound is expected to adequately exhibit the effect thereof. When n⁴ is 6 or less, the solubility of the compound in a lubricant base oil is better.

The alkyl group includes a polybutenyl group, a polyisobutyl group, an ethylene-propylene copolymer. The alkenyl group includes those prepared by hydrogenating these. A polybutenyl group or a polyisobutyl group is a preferred alkyl group. The polybutenyl group is preferably one prepared through polymerization of a mixture of 1-butene and isobutene, or polymerization of high-purity isobutene. Specific examples of a preferred alkyl group include those prepared by hydrogenating a polybutenyl group or a polyisobutyl group.

The boron-modified succinimide may be obtained, for example, by reacting a polyolefin and a maleic anhydride to give an alkenylsuccinic anhydride (A), separately reacting a polyamine and a boron compound to give an intermediate (B), and reacting the alkenylsuccinic anhydride (A) and the intermediate (B) for imidation. The monoimide or the bisimide may be produced by varying the ratio of the alkenylsuccinic anhydride or the alkylsuccinic anhydride to the polyamine.

The boron-modified succinimide may also be produced by treating an alkenyl or alkylsuccinic acid monoimide or an alkyl or alkylsuccinic acid bisimide not containing boron, with a boron compound.

As the olefin monomer to form the above-mentioned polyolefin, one alone or two or more kinds of α-olefins having 2 to 8 carbon atoms may be used either singly or as a mixture. A mixture of isobutene and 1-butene is preferably used.

On the other hand, the polyamine includes simple diamines such as ethylenediamine, propylenediamine, butylenediamine, pentylenediamine, etc.; polyalkylkylene- olyamines such as diethylkylene diamine, triethylenetetramine, tetraethylenepentamine, pentaethylenhexamine, di(methylene) triamine, dibutylenetetramine, tributylenetetramine, pentapentahexamine, etc.; piperazine derivatives such as aminoethylpiperazine, etc.

The boron compound includes boric acid, boric acid salts, boric acid esters, etc.

The boron acid includes orthoboric acid, metaboric acid, paraboric acid, etc. The boric acid salt includes ammonium borate such as ammonium metaborate, ammonium tetraborate, ammonium pentaborate, ammonium octaborate, etc. The boric acid ester includes monomethyl borate, dimethyl borate, trimethyl borate, monooethyl borate, diethyl borate, triethyl borate, monopropyl borate, dipropyl borate, tripropyl borate, monobutyl borate, dibutyl borate, tributyl borate, etc.

The ratio of the boron atom amount contained in the boron-modified succinimide (B:N ratio) is from 0.8 to 2.0, more preferably 0.6 or more on a mass standard, more preferably 0.7 or more, even more preferably 0.8 or more. The B:N ratio is, though not specifically limited thereto, preferably 2.0 or less, more preferably 1.5 or less, even more preferably 1.3 or less.

Preferably, from the viewpoint of friction reduction, the boron-modified succinimide contains a large amount of 3-coordinated boron-modified succinimide, etc., more preferably in a ratio by mol of 0.50 or more relative to the total amount of the 3-coordinated and 4-coordinated boron-modified succinimides, more preferably in a ratio by mol of 0.60 or more, even more preferably 0.65 or more.

The ratio of the 3-coordinated boron-modified succinimide and the 4-coordinated boron-modified succinimide may be measured, for example, through ¹¹B-NMR based on BF₃·OEt₃ standard (0 ppm). In the ¹¹B-NMR, a peak for the 3-coordinated boron-modified succinimide appears at 5 to 25 ppm, and a peak for the 4-coordinated boron-modified succinimide appears at -10 to 5 ppm, and therefore, by calculating the integrated value of each peak, the above-mentioned ratio can be calculated.

In this embodiment, the content of the boron-modified succinimide is preferably 0.1 to 15.0% by mass in the lubricating oil composition for internal combustion engines, more preferably 0.2 to 10.0% by mass, even more preferably 0.5 to 5.0% by mass, still more preferably 0.5 to 2.0% by mass. When the content of the boron-modified succinimide falls within the above range, the lubricating oil composition can reduce friction more efficiently from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher and can better detergency.

In this embodiment, the boron atom-equivalent content of the boron-modified succinimide is preferably 0.2% by mass or less in the lubricating oil composition for internal combustion engines, more preferably 0.001 to 0.05% by mass, even more preferably 0.005 to 0.03% by mass. When the boron atom-equivalent content of the boron-modified succinimide falls within the above range, the lubricating oil composition can reduce friction more efficiently from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher and can better detergency.

In this embodiment, the ratio by mass of the content of the surfactant to the content of the boron-modified succinimide (content of boron-modified succinimide/content of surfactant) is preferably 100 or less, more preferably 20 or less, even more preferably 5 or less. When the ratio by mass falls within the above range, the lubricating oil composition can reduce friction more efficiently from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher and can better detergency.

In this embodiment, the ratio by mass of the content of the surfactant to the content of the boron atom-equivalent content of the boron-modified succinimide (boron atom-equivalent content of boron-modified succinimide/
content of surfactant) is preferably 1 or less, more preferably 0.2 or less, even more preferably 0.05 or less. When the ratio by mass falls within the above range, the lubricating oil composition can reduce friction more efficiently from a low-temperature range assuming engine starting to a practical temperature range of 80°C. or higher and can satisfy more readily both friction reduction and detergency.

Poly(meth) Acrylate

[0066] Preferably, the lubricating oil composition for internal combustion engines of this embodiment further contains a poly(meth)acrylate as a viscosity index improver.

[0067] By containing a poly(meth)acrylate, the lubricating oil composition can improve fuel-saving performance more efficiently in addition to the effect of improving fuel-saving performance owing to friction reduction by the surfactant and the non-oxidized sucrose ester therein.

[0068] The monomer to constitute the poly(meth)acrylate is an alkyl (meth)acrylate and is preferably an alkyl (meth)acrylate having a linear alkyl group with 1 to 18 carbon atoms or a branched alkyl group with 3 to 34 carbon atoms.

[0069] Preferred examples of the monomer to constitute alkyl (meth)acrylate include methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, butyl (meth)acrylate, pentyl (meth)acrylate, hexyl (meth)acrylate, heptyl (meth)acrylate, octyl (meth)acrylate, nonyl (meth)acrylate, decyl (meth)acrylate, dodecyl (meth)acrylate, tetra-(meth)acrylate, hexa-(meth)acrylate, octadecyl (meth)acrylate, etc. Two or more kinds of these monomers may be used to give a copolymer. The alkyl group of these monomers may be linear or branched.

[0070] The alkyl (meth)acrylate having a branched alkyl group with 3 to 34 carbon atoms includes isopropyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, 3,5,5-trimethylhexyl (meth)acrylate, 2-butylcyclohexyl (meth)acrylate, 2-hexylcyclohexyl (meth)acrylate, 2-cyclohexyl(2-decyl)cyclohexyl (meth)acrylate, 2-decyltetradecyl (meth)acrylate, 2-dodecylhexadecyl (meth)acrylate, 2-tetradecyloctadecyl (meth)acrylate.

[0071] The poly(meth)acrylate is preferably one having a weight-average molecular weight of 100,000 to 600,000, more preferably 15,000 to 300,000.

[0072] In this embodiment, “weight-average molecular weight” is meant to indicate a polystyrene-equivalent molecular weight measured through gel permeation chromatography (GPC).

[0073] SSI of the poly(meth)acrylate is preferably 30% or less, more preferably 1 to 28%. When the weight-average molecular weight thereof falls within the above range, the poly(meth)acrylate may have SSI of 30% or less.

[0074] Here, SSI means a shear stability index, and indicates the decomposition resistance of the poly(meth)acrylate. Having a larger SSI value, the polymer is more unstable against shearing and is decomposed more readily.

\[
\text{SSI} = \frac{K_{vo} - K_{vi}}{K_{vo} - K_{v0}} \times 100 \quad \text{[Math. 1]}
\]

[0075] SSI is to indicate viscosity reduction by polymer-derived shearing as percentage, and is calculated according to the above-mentioned calculation formula. In the formula, \(K_{vo}\) is a value of 100°C. C. kinematic viscosity of a mixture prepared by adding a poly(meth)acrylate to a base oil. \(K_{v1}\) is a value of 100°C. C. kinematic viscosity of a mixture prepared by adding a poly(meth)acrylate to a base oil after the mixture has made to pass through a high-shear Bosch diesel injector for 30 cycles according to a process of ASTM D6278. \(K_{v0}\) is a value of 100°C. C. kinematic viscosity of a base oil. As the base oil, Group-II base oil having a 100°C. C. kinematic viscosity of 5.35 mm²/s and a viscosity index of 105 is used.

[0076] The content of the poly(meth)acrylate is, from the viewpoint of fuel-saving performance, preferably 1 to 15% by mass in the lubricating oil composition for internal combustion engines, more preferably 2 to 10% by mass, even more preferably 3 to 8% by mass.

<Additive>

[0077] From the viewpoint of friction reduction, preferably, the lubricating oil composition for internal combustion engines of this embodiment further contains a molybdenum compound.

[0078] The molybdenum compound includes MoDTC (molybdenum dialkyl dithiophosphinate), MoDTP (molybdenum dialkyl dithiocarbamate), etc.

[0079] The content of the molybdenum compound is preferably 2.0% or less by mass in the lubricating oil composition for internal combustion engines, more preferably 0.1 to 1.0% by mass.

<Additive>

[0080] The lubricant base oil includes a mineral oil and/or a synthetic oil.

[0081] The mineral oil includes a parafln-base mineral oil, an intermediate-base mineral oil, a naphtheno-base mineral oil and the like produced through ordinary purification such as solvent purification, hydrogenation purification, etc.; a wax-isomerized oil produced through isomerization of a wax such as a wax (gas-to-liquid gas) produced according to a Fischer Tropsch process or the like, a mineral oil wax, etc.

[0082] The synthetic oil includes a hydrocarbon synthetic oil, an ether synthetic oil, etc. The hydrocarbon synthetic oil includes olefin oligomers or hydrocarbons thereof such as a polybutene, a polyisobutylene, a 1-ocene oligomer, a 1-decene oligomer, an ethylene-propylene copolymer, etc.; alkylbenzenes, alkylphenyl ethers, etc.

[0083] The lubricant base oil may be a single system using one kind of the above-mentioned mineral oils and synthetic oils, or may be also a mixed system, such as a mixture prepared by mixing two or more kinds of mineral oils, a mixture prepared by mixing two or more kinds of synthetic oils, or a mixture prepared by mixing one or more kinds of mineral oils and one or more kinds of synthetic oils.

[0084] In particular, as the lubricant base oil, use of one or more kinds selected from mineral oils and synthetic oils classified in Group 3 or Group 4 in base oil classification by American Petroleum Institute is preferred.

[0085] The content of the lubricant base oil is preferably 70% by mass or more and less than 100% by mass in the lubricating oil composition for internal combustion engines, more preferably 75% by mass or more and 95% by mass or less, even more preferably 80% by mass or more and 90% by mass or less.
Examples

Next, the present embodiment is described in more detail with reference Examples.

1. Preparation of Lubricating Oil Composition for Internal Combustion Engines

The lubricating oil compositions for internal combustion engines of Examples, Comparative Examples and Reference Example were prepared according to the compositional ratio shown in Table 1. The lubricating oil compositions for internal combustion engines of Examples, Comparative Examples and Reference Examples were all so controlled as to have an HTHS viscosity at 150° C. of 2.6 mPa.s.

2. Measurement and Evaluation

The lubricating oil compositions for internal combustion engines of Examples, Comparative Examples and Reference Example were measured and evaluated as follows. The results are shown in Table 1.

2-1. Kinematic Viscosity

According to the description of the main text of the present invention, the 40° C. kinematic viscosity and 100° C. kinematic viscosity of each lubricating oil composition for internal combustion engines were measured.

2-2. Friction Coefficient

The friction coefficient of each lubricating oil composition for internal combustion engines was measured under the condition mentioned below.

Test: MTM (Mini Traction Machine) tester, manufactured by PCS Instruments Corporation

Test Piece: Standard test piece

Rubbing Time: 2 hours

Oil Temperature: 80° C.

Load: 10 N

Measuring Speed: 1.2 m/s

TABLE 1

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[0102] The materials in Table 1 are as follows.

[Lubricant Base Oil]

[0103] Mineral oil having 100°C, kinematic viscosity of 4.07 mm²/s, viscosity index: 131, % C₁₀: -0.4, % C₁₂: 12.8, % C₁₅: 87.6

<Surfactant A>

[0104] Mixture of 69% by mass of tertiary amine of general formula (I) (x=0, n₁+n₂=10, number of carbon atoms in A¹O and A²O: 2, R¹: oleyl group) and 31% by mass of tertiary amine of general formula (I) (x=0, n₁+n₂=10, number of carbon atoms in A¹O and A²O: 2, R¹: stearyl group) (mass ratio was measured through liquid chromatography mass spectrometry). HLB value: 13.2. Peak appearing position in mass spectrum in liquid chromatography mass spectrometry: 440 to 940 m/z (nearly equal to molecular weight range: 440 to 940 g/mol).

[0105] The condition for liquid chromatography mass spectrometry is as follows.

<Condition for Liquid Chromatography Mass Spectrometry>

[0106] Detector: Photodiode array detector, evaporative light scattering detector

[0107] Column: Inertsil ODS (3.0×150 mm, 3 μm)

[0108] Mobile Phase: A) MeCN/(0.1% formic acid+0.1% ammonium formate)=80/20

[0109] B) THF


[0111] Ion Source: Heated ESI positive, negative

[0112] m/z Range: 150 to 1000

<Surfactant B>

[0113] Mixture of 85% by mass of tertiary amine of general formula (I) (x=0, n₁+n₂=7, number of carbon atoms in A¹O and A²O: 2, R¹: oleyl group) and 15% by mass of tertiary amine of general formula (I) (x=0, n₁+n₂=10, number of carbon atoms in A¹O and A²O: 2, R¹: stearyl group) (mass ratio was measured through liquid chromatography mass spectrometry). HLB value: 11.7. Peak appearing position in mass spectrum in liquid chromatography mass spectrometry: 400 to 850 m/z (nearly equal to molecular weight range: 400 to 850 g/mol).

<Surfactant C>

[0114] Polyoxyalkylene fatty acid ester (HLB value: 11.1, number of carbon atoms of oxyalkylene group: 2, average addition molar number of oxyalkylene group: 5, number of carbon atoms of constituent unit derived from fatty acid: 18)

<Surfactant D>

[0115] Trade name: Ethomeen O12, manufactured by Lion Akzo Corporation, substance name: polyoxyethylene oleylamine (tertiary amine of general formula (I) where x=0, n₁+n₂=2, number of carbon atoms in A¹O and A²O: 2), HLB value 6.5, weight-average molecular weight: 356

<Surfactant E>

[0116] Trade name: INFINEUM-C 9440, manufactured by Infineum Corporation, substance name: glycerol monooleate

<Boron-Modified Succinimide>

[0117] Boron-modified polybutenylsuccinic acid bisimide, ratio of 3-coordination to 4-coordination (integral value of peaks of 3-coordination/integral value of peaks of 4-coordination-integral value of peaks of 3-coordination): 0.67, boron atom amount/nitrogen atom amount: 1.1, boron content: 1.30% by mass, nitrogen content: 1.23% by mass

<MoDTC>

[0118] MoDTC having an Mo content of 0.07% by mass

<Polymethacrylate>

[0119] Weight-average molecular weight: 230,000, SSI: 25.2%

<Metallic Detergent>

[0120] Calcium salicylate, calcium content: 7.8% by mass, overbased, base number 224 mg-KOH/g

<Antioxidant>

[0121] Phenol-based antioxidant, trade name: IRGANOX-L 135, manufactured by BASF Corporation

<Package Additive>

[0122] Package additive containing ZnDTP, high-molecular bisimide, amine antioxidant
From the results in Table 1, it is confirmed that the lubricating oil compositions for internal combustion engines of Examples 1 to 4 are excellent in the friction-reducing effect in a practical temperature range of 80°C or higher through using an ash-free friction reducer. In particular, it is confirmed that the lubricating oil composition for internal combustion engines of Example 3 using both a surfactant having an alkylene oxide as the constituent unit and having an HLB value of 7 or more and less than 15, and a boron-modified succinimide is extremely excellent in the above-mentioned effect.

2-3. Detergency

The lubricating oil compositions for internal combustion engines of Examples 1 and 3, Comparative Examples 1 to 3 and Reference Example were further evaluated in point of detergency.

From the results in Table 2, it is confirmed that the lubricating oil composition for internal combustion engines of Example 3 using both a surfactant having an alkylene oxide as the constituent unit and having an HLB value of 7 or more and less than 15, and a boron-modified succinimide can further better detergency.

INDUSTRIAL APPLICABILITY

Taking advantage of the characteristics thereof of reducing friction and bettering fuel-saving performance from a low-temperature range assuming engine starting to a practical temperature range of 80°C or higher, the lubricating oil composition for internal combustion engines of this embodiment can be favorably used for various internal combustion engines for four-wheel cars, two-wheel cars, etc. Among internal combustion engines, the composition is especially favorably used for gasoline engines.

1. A lubricating oil composition for internal combustion engines, the composition comprising:
   - a surfactant having an alkylene oxide as the constituent unit and having an HLB value of 7 or more and less than 15, and
   - a lubricant base oil.

2. The lubricating oil composition for internal combustion engines according to claim 1, wherein the surfactant has a molecular weight in a range of 350 to 950 g/mol.

3. The lubricating oil composition for internal combustion engines according to claim 1, wherein the surfactant is an amine compound.

4. The lubricating oil composition for internal combustion engines according to claim 1, wherein the amine compound is a tertiary amine.

5. The lubricating oil composition for internal combustion engines according to claim 1, wherein the surfactant is a polyoxyalkylene fatty acid ester.

6. The lubricating oil composition for internal combustion engines according to claim 1, wherein a content of the surfactant in the lubricating oil composition is 0.1 to 2.0% by mass.

7. The lubricating oil composition for internal combustion engines according to claim 1, further comprising:
   - a boron-modified succinimide.

8. The lubricating oil composition for internal combustion engines according to claim 7, wherein a boron atom-equivalent content of the boron-modified succinimide in the lubricating oil composition is 0.2% by mass or less.

9. The lubricating oil composition for internal combustion engines according to claim 7, wherein a ratio by mass of a content of boron-modified succinimide/a content of the surfactant is 100 or less.

10. The lubricating oil composition for internal combustion engines according to claim 7, wherein a ratio by mass of a content of boron atom-equivalent content of the boron-modified succinimide/a content of the surfactant is 20 or less.

11. The lubricating oil composition for internal combustion engines according to claim 1, further comprising:
   - a poly(meth)acrylate.

12. The lubricating oil composition for internal combustion engines according to claim 1, wherein the lubricant base oil is at least one of a mineral oil and a synthetic oil classified in Group 3 and Group 4 in base oil classification by American Petroleum Institute.
13. The lubricating oil composition for internal combustion engines according to claim 1, which has a kinematic viscosity at 100° C. of 3.8 to 12.5 mm²/s.

14. The lubricating oil composition for internal combustion engines according to claim 1, which is adapted to function as a lubricating oil composition for gasoline engines.

15. A friction reducing method for gasoline engines, the method comprising adding the lubricating oil composition of claim 1 to a gasoline engine.

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