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(54) Title: LUBRICATING OIL COMPOSITION FOR AN INTERNAL-COMBUSTION ENGINE

(57) Abstract: A lubricating oil composition for an internal combustion engine comprising: (A) at least one base oil selected from the group consisting of base oils classified as Group 2, 3, or 4 by API (US Petroleum Institute) base oil category and showing a dynamic viscosity at 100°C of 3.0 to 12.0 mm^2/s, (B) a monoglyceride having C_8-C_{22} carbohydrate groups and a hydroxyl value of 150 to 350 mgKOH/g, in an amount of 0.3 to 2.0 mass% in terms of the total amount of composition, and (C) a fatty acid ester having an HLB value of 1.0 to 4.0, or a fatty acid ester derivative wherein polyoxyethylene has been added to this fatty acid ester, in an amount that is at least 0.7 mass% based on the total amount of composition.

LUBRICATING OIL COMPOSITION FOR INTERNAL COMBUSTION ENGINE

Field of the Invention

The present invention relates to a lubricating oil composition for an internal combustion engine to which a monoglyceride (partial ester of a fatty acid and glycerin) has been added as the friction modifier for fuel efficiency in an internal combustion engine (also referred to simply as engine hereafter), which is an engine oil lubricating oil composition for an energy efficient automobile with which the water of condensation, and the like from the water vapor that is produced when fuel is burned in the internal combustion engine, and the like is dispersed in the engine oil and excellent performance in terms of preventing engine corrosion and rusting is thereby realized.

Background of the Invention

Today's automobiles have an idling stop function that is signalled to operate when the automobile stops. As a result, the engine stops frequently when running on city roads. Therefore, when the vehicle is operated for short distances, in order to shop for instance, the oil temperature of the lubricating oil for the internal combustion does not become hot enough and operation stops before the water mixed in the oil can be evaporated in the oil pan and emitted. Similarly, when a PHV (plug-in-hybrid vehicle) is operated for short distances in order to go to work or go shopping by on-off engine rotation as necessary, it is stopped before the engine has become hot enough. Therefore, water vapor that is produced by

burning fuel enters the engine room with the blow-by gas. Because the engine is not hot enough, that water vapor condenses in the oil pan to form water droplets and becomes mixed in the lubricating oil for the internal combustion engine.

Furthermore, recyclable biofuel is being used in gasoline and light oil for automobiles in order to reduce CO2 and thereby prevent global warming.

For instance, on the basis of "Sophisticated Methods of Energy Supply Structures of Japan", progress is being made in planning for annual reduction in greenhouse gases (CO2) by adding a recyclable biofuel to automobile gasoline. Actually, 210,000 KL/year of biofuel in terms of crude oil was used for automobile gasoline in 2010, and there are plans to use 500,000 KL/year of biofuel in terms of crude oil by the year 2017.

These biofuels, specifically bioethanol and ETBE (ethyl tert-butyl ether: ethyl tert-butyl ether), are fuels for internal combustion engines having a high percentage of hydrogen element in the hydrocarbons (H/C) used in the fuel and generate large amounts of water (water vapor) with combustion when compared to ordinary fuels. The commercial premium gasoline and regular gasoline H/C (carbon hydrogen ratio) is 1.763 and 1.875, relatively, when calculated based on the carbon concentration in Table 2.4-1 of "Japan Petroleum Energy Center, 2005 Report of the Results of Automobile Fuel Research PEC-2005JC-16,2-14". When 3% of this premium gasoline and regular gasoline is substituted with (bio)ethanol, and the like, the H/C becomes 1.80 and 1.91, respectively. Thus, by using biofuel for gasoline, the H/C is raised and the CO2 with combustion is reduced.

However, large amounts of water vapor are generated. Similarly in terms of the H/C of commercial diesel fuel, according to Table 4.1.1-2 of "Japan Petroleum Energy Center, 2008 Research and Development Report on Diversification and High-Efficiency Use of Automobile Fuel" 14, the H/C of "BASE," which is the equivalent of commercial No. 2 diesel fuel, is 1.91, and according to Table 2 of "National Traffic Safety and Environmental Laboratory, Forum 2011 Data, Trends in Automobile Advanced Fuels at the International Energy Agency (IEA) and Actions of the National Traffic Safety and Environmental Laboratory", the H/C of diesel fuel JIS No. 2 is 1.927. When 5% of these diesel fuels are substituted with methyl stearate as a typical biodiesel fuel, the H/C increases to approximately 1.93 and the amount of CO2 generated by combustion is reduced, but the amount of water vapor generated is increased.

The same is true of engines for vehicles that use as the fuel natural gas, LPG, or propane, which have a higher hydrogen element ratio (H/C) than gasoline or diesel fuel.

According to today's gasoline engine oil regulations, API-SN + RC (Resource Conserving) and ILSAC GF-5 regulations, even vehicles that use E85 fuel containing bioethanol require retention of emulsified (condensed) water and E85 fuel in internal combustion engine oil such that when water and natural ethanol are mixed in the internal combustion engine oil by combustion, water droplets do not precipitate at the metal surface and rust or corrode the surrounding surface (ASTM D7563; emulsion retention). The method for determining emulsion retention (emulsion stability) is a test that is

specified by ASTM D7563. This test involves evaluating stability by confirming that even when (condensed) water or E85 fuel is mixed in an internal combustion engine oil that is used, they are encapsulated in the oil in emulsion form and will not precipitate to the surface or separate such as to avoid corrosion or rusting of the parts of the internal combustion engine.

On the other hand, recently an ash-free friction modifier such as a fatty acid ester has been added to a lubricating oil for internal combustion engines in order to reduce metal-on-metal friction and improve fuel efficiency in an internal combustion engine (for instance, refer to JP (Kokai) 2004-155881 and Tribologist, Naoto Namiki, Volume 48, Number 11 (2003), 903-909).

Although organic molybdenum compounds, and the like are often used as friction modifiers, in recent years ash-free friction modifiers (which are free of metals and elements such as phosphorus and therefore do not produce an ash component with combustion) have been preferred because they do not have a detrimental effect on exhaust gas catalysts and exhaust gas treatment devices such as diesel particulate filters (DPF).

These ash-free friction modifiers used in lubricating oils for internal combustion engines do not contain metals or elements such as phosphorus. Therefore, they have little effect on exhaust gas catalysts and exhaust gas post-treatment systems and are easily used for lubricating oils for internal combustion engines. On the other hand, because they have the effect of a surfactant, in some cases they can enhance anti-emulsification performance and water separation performance in internal combustion engine oils. As a

result, when the water vapor formed by combustion of fuel becomes condensed water that has mixed in the oil, water tends to form on the metal surfaces of engine parts. The precipitated water contains oxidized fuel residue and can cause rusting and corrosion at the metal surfaces of the engine parts.

In particular, monoglyceride ash-free friction modifiers are known to have an improved friction-reducing effect and are ideal for compositions of lubricating oils for internal combustion engines. However, the water of condensation that is produced by the water vapor that is generated with fuel combustion and mixes in the engine oil has the potential to increase anti-emulsification performance and water separation performance.

Therefore, there is a need for a lubricating oil composition for an internal combustion oil that has excellent antiwear performance and fuel efficiency (low-friction properties) and has the property of causing the water of condensation, and the like from the water vapor generated by fuel consumption to disperse in the oil and thereby preventing corrosion and rusting of the internal combustion engine.

The present invention is in the light of these conditions, and the purpose thereof is to provide an engine oil lubricating oil composition for an energy-efficient automobile with which water of condensation, and the like from the water vapor that is produced when fuel is burned in the internal combustion engine, and the like is dispersed in the engine oil and thereby has excellent performance in terms of preventing engine corrosion and rusting.

The inventors confirmed the anti-emulsification

performance and water separation performance of a monoglyceride having a specific structure that is used as an ash-free friction modifier in a specific lubricating oil for an internal combustion engine {one or more base oils selected from the group consisting of base oils classified as Groups 2, 3, and 4 by API (American Petroleum Institute) base oil category having a dynamic viscosity at 100°C of 3.0 to 12.0 mm2/s}. As a result, they ascertained that although when a specific amount of the monoglyceride having a specific structure is added, excellent antiwear performance and the like can be realized, when the water of condensation from the water vapor that is generated by fuel combustion by the engine mixes in the engine oil, anti-emulsification performance and water separation performance are increased in relationship with the above-mentioned specific lubricating oil for an internal combustion engine and water easily separates to the surface (a trade-off relationship is established). Therefore, there is a reduction in corrosion resistance and anti-rusting performance when the monoglyceride having a specific structure is used alone. Thus, the above-mentioned specific lubricating oil composition for an internal combustion engine that comprises the monoglyceride having a specific structure is not appropriate for the newest gasoline engine oil regulations API-SN+RC and ILSAC GF-5.

Therefore, the inventors performed extensive research in order to improve the emulsion stability of the above-mentioned composition (that is, a combination of a specific base oil and a specific amount of a monoglyceride having a specific structure) and successfully completed the present invention upon

discovering that excellent antiwear performance and fuel efficiency are obtained and emulsion stability is improved by a lubricating oil for an internal combustion engine wherein a fatty acid ester having an HLB of 1.0 to 4.0, or a fatty acid ester derivative wherein a polyoxyethylene is added to the fatty acid ester, is added within a specific range.

Summary of the Invention

According to one aspect of the present invention there is provided a lubricating oil composition for an internal combustion engine comprising:

(A) at least one base oil selected from the group consisting of base oils classified as Group 2, 3, or 4 by API (US Petroleum Institute) base oil category and showing a dynamic viscosity at 100°C of 3.0 to 12.0 mm2/s,

(B) a monoglyceride having C8-C22 carbohydrate groups and a hydroxyl value of 150 to 350 mgKOH/g, in an amount of 0.3 to 2.0 mass% in terms of the total amount of composition, and

(C) a fatty acid ester having an HLB value of 1.0 to 4.0, or a fatty acid ester derivative wherein polyoxyethylene has been added to this fatty acid ester, in an amount that is at least 0.7 mass% in terms of the total amount of composition.

Preferably, the lubricating oil composition herein is characterized in being used in an internal combustion engine that uses fuel having an H/C ratio of 1.75 to 4, an internal combustion engine of a vehicle with an idling stop device, or an internal combustion engine that uses a fuel to which a biofuel or a biodiesel fuel has been added.

Preferably, the lubricating oil composition herein

is characterized in that the fatty acid ester is a sorbitan fatty acid ester.

Preferably, the lubricating oil composition herein is characterized in that the fatty acid ester is a fatty acid triester.

Detailed Description of the Invention

By means of the present invention, a lubricating oil composition for an internal combustion engine is obtained which has excellent antiwear performance and fuel efficiency and the property of causing the water of condensation, and the like from water vapor generated by combustion, and the like of fuel to disperse such as to form a stable emulsion in oil and thereby preventing internal combustion engine corrosion and rusting.

A preferred embodiment of the present invention will now be described in detail. It should be noted that this embodiment is only one embodiment of the present invention, and the technical scope of the invention is not restricted to this embodiment.

The lubricating oil composition for an internal combustion engine relating to the present invention will be explained in the following order.

1 Lubricating oil composition Components

2 Lubricating oil composition Properties

3 Lubricating oil composition Uses

The present invention relates to a lubricating oil composition for an internal combustion engine comprising:

(A) at least one base oil selected from the group consisting of base oils classified as Group 2, 3, or 4 by API (US Petroleum Institute) base oil category and showing a dynamic viscosity at 100°C of 3.0 to 12.0 mm2/s,

(B) a monoglyceride having C8-C22 carbohydrate groups

and a hydroxyl value of 150 to 350 mgKOH/g, in an amount of 0.3 to 2.0 mass% in terms of the total amount of composition, and

(C) a fatty acid ester having an HLB value of 1.0 to 4.0, or a fatty acid ester derivative wherein polyoxyethylene has been added to this fatty acid ester, in an amount that is at least 0.7 mass% in terms of the total amount of composition.

Lubricating Oil Composition – Components

The lubricating oil composition for an internal combustion engine relating to the present embodiment (also sometimes referred to simply as "lubricating oil composition hereafter) comprises as its components a base oil, a monoglyceride, a fatty acid ester or derivative thereof, and other additives as necessary. Each of these components will now be described in detail.

Base Oil

A mineral oil or hydrocarbon synthetic oil referred to as a highly purified base oil can be used as the base oil of the lubricating oil composition. In particular, it is possible to use one or a mixture of base oils selected from the group consisting of base oils classified as Group 2, Group 3, or Group 4 by API (American Petroleum Institute) base oil categories. The base oil that is used here is one having a dynamic viscosity at 100°C of 3.0 to 12.0 mm2/s, preferably 3.0 to 10.0 mm2/s, more preferably 3.0 to 8.0 mm2/s. The viscosity index of the base oils can be 100 to 180, preferably 100 to 160, more preferably 100 to 150. The sulfur element component of the base oil is 300 ppm or less, preferably 200 ppm or less, more preferably 100 ppm or less, further preferably 50 ppm or less. Moreover,

density of the base oil at 15°C is 0.80 to 0.95 g/cm3, preferably 0.80 to 0.90 g/cm3, more preferably 0.80 to 0.85 g/cm3. The base oil aromatic content % CA (the aromatic content in the present invention is determined by n-d-M analysis: ASTM D 3238) is less than 5, preferably less than 4, more preferably less than 3.

Examples of Group 2 base oils are paraffin-based oils obtained by, for instance, subjecting a lubricating oil fraction obtained by reduced-pressure distillation of crude oil to the appropriate combination of purification means, such as hydrocracking, dewaxing, and the like, and then using the product. The Group 2 base oil purified by the hydrogenation method of Gulf, for instance, has a total sulfur content of less than 10 ppm and an aromatic content % CA of 5 or less. It is ideal as a base oil to be added to the lubricating oil composition of the present invention. The Group 2 base oil preferably has a viscosity index (viscosity index in the present invention as determined by ASTM D2270 and JIS K2283) of 100 or greater but less than 120, further preferably 105 or greater but less than 120. Dynamic viscosity at 100°C of the Group 2 base oil (in the present invention, dynamic viscosity as determined by ASTM D445 and JIS K2283) is preferably 3.0 to 12.0 mm2/s, more preferably 3.0 to 9.0 mm2/s. Moreover, the Group 2 base oil has a total sulfur content of preferably less than 300 ppm, more preferably less than 200 ppm, further preferably less than 100 ppm, particularly preferably less than 10 ppm. The total sulfur content is the value as determined using the radiation-type excitation method (in accordance with ASTM D4294, JIS K 2541-4). The total nitrogen content of the Group 2 base oil is less than 10 ppm, preferably less

than 1 ppm. Furthermore, the aniline point of the group 2 base oil (the aniline point of the present invention is determined by ASTM D611, JIS K2256) preferably 80 to 150°C, more preferably 100 to 135°C.

Examples of Group 3 base oil are, for instance "paraffin-based mineral oils obtained by subjecting a lubricating oil fraction obtained by reduced-pressure distillation of a starting oil to high-degree hydrocracking," "a base oil purified by subjecting the GTL (gas tow liquid) synthesized by subjecting natural gas to Fischer-Tropsch methods, or wax produced via dewaxing, to solvent dewaxing and then purification by the ISODEWAX process, which is a process involving conversion to isoparaffin and then dewaxing," and "a base oil purified by ExxonMobil's wax isomerization (WAX)." The viscosity index of the Group 3 base oil is preferably 100 to 150, further preferably 100 to 140. Dynamic viscosity at 100°C of the Group 3 base oil is preferably 3.0 to 12.0 mm2/s, more preferably 3.0 to 9.0 mm2/s. Moreover, the total sulfur content of the Group 3 base oil is preferably less than 100 ppm, more preferably less than 10 ppm. The total nitrogen content of the Group 3 base oil is preferably less than 10 ppm, more preferably less than 1 ppm. Furthermore, the aniline point of the Group 3 base oil is preferably 80 to 150°C, further preferably 110 to 140°C.

The Group 4 base oil is poly-alpha-olefin (poly-α-olefin), alpha-olefin oligomer (α-olefin oligomer), or mixtures thereof (mixtures of poly-alpha-olefin and alpha-olefin oligomer). The poly-alpha-olefin (PAO) is a polymer of any of a variety of alpha-olefins (monomers). Moreover, the poly-alpha-olefin can be a polymer of one

type of "alpha-olefin (monomer)," or a mixture of several polymers of "alpha-olefins (monomers)." The alpha-olefin oligomer is an oligomer of any of a variety of alpha-olefins (monomers), and also includes hydrogenated alpha-olefin (monomer) oligomers. The alpha-olefin (monomer) is not particularly restricted, and examples are ethylene, propylene, butene, and alpha olefins having 5 or more carbons.

In addition, GTL (gas to liquid) oil synthesized by Fischer-Tropsch liquefaction of natural gas has a very low sulfur content and aromatic content and has a very high paraffin structural ratio when compared to mineral oil base oils purified from crude oil and therefore, has excellent oxidation stability and very low evaporation loss and is ideal as the base oil of the present embodiment. There are no particular restrictions to the viscosity of the GTL base oil, but the viscosity index is preferably 100 to 180, further preferably 100 to 150. Moreover, the dynamic viscosity at 100°C is preferably 3.0 to 12.0 mm2/s, more preferably 3.0 to 9.0 mm2/s.

In addition, the total sulfur content should be less than 10 ppm and the total nitrogen content should be less than 1 ppm in each case. An example of such a GTL base oil commercial product is Shell XHVI (registered trademark).

Examples of hydrocarbon synthetic oils are polyolefins, alkyl benzene, alkyl naphthalenes, and the like containing PAO, and the like, or mixtures thereof.

The viscosity of these synthetic base oils is not particularly restricted, but dynamic viscosity at 100°C is preferably 3.0 to 12.0 mm2/s, more preferably 3.0 to 10.0 mm2/s, further preferably 3.0 to 8.0 mm2/s. The

viscosity index of the synthetic base oil is preferably 10 to 120, more preferably 20 to 120, further preferably 20 to 110, in the case of alkylbenzene or alkyl naphthalene, and preferably 100 to 170, more preferably 110 to 170, and further preferably 110 to 155, in the case of poly-alpha-olefin. The density at 15°C of this synthetic base oil is preferably 0.8000 to 0.9500 g/cm3, more preferably 0.8100 to 0.9500 g/cm3, further preferably 0.8100 to 0.9200 g/cm3.

Furthermore, a base oil belonging to Group 1 by API (American Petroleum Institute) base oil category, can be added to the base oil as the base oil of the lubricating oil composition. An example of a Group 1 base oil is a paraffin-based mineral oil obtained by, for instance, subjecting a lubricating oil fraction obtained by reduced-pressure distillation of crude oil to the appropriate combination of purification means, such as solvent purification, hydrogenation, and dewaxing. The Group 1 base oil that is used here has a dynamic viscosity at 100°C of 3.0 to 12.0 mm2/s, preferably 3.0 to 10.0 mm2/s, more preferably 3.0 to 8.0 mm2/s. Moreover, the viscosity index is 90 to 120, preferably 95 to 115, further preferably 95 to 110. In addition, the sulfur content is 0.03 to 0.7 mass%, preferably 0.1 to 0.7 mass%, more preferably 0.4 to 0.7 mass%. In addition, the %CA by ASTM D3238 is 5 or less, preferably 4 or less, more preferably 3.4 or less. Moreover, the %CP by ASTM D3238 is 60 or greater, preferably 63 or greater, more preferably 66 or greater.

The content of the above-mentioned base oil in the lubricating oil composition of the present embodiment is not particularly restricted, but an example is 50 to 90

mass%, preferably 60 to 90 mass%, more preferably 70 to 85 mass%, in terms of the total amount of lubricating oil composition. It should be noted that when a base oil belonging to Group 1 is added as the base oil of the lubricating oil composition of the present invention, the amount added in terms of the total amount of lubricating oil composition is preferably 10 mass% or less. There is little effect on the antiwear performance and the friction-reducing effect of the lubricating oil composition when the Group 1 base oil is added within the above-mentioned range.

Monoglyceride

The monoglyceride used as the ash-free friction modifier is a partial ester of a fatty acid and glycerin, and in further detail, a glycerin fatty acid ester where a fatty acid forms an ester bond with one of three hydroxyl groups of the glycerin. (It should be noted that the monoglyceride in the present invention can also contain an impurity in the form of diglyceride (a glycerin fatty acid ester where a fatty acid forms ester bonds with two of the three hydroxyl groups of the glycerin)). The number of carbons in the hydroxyl groups of the fatty acid of the monoglyceride is preferably 8 to 22. When the number of carbon atoms in the hydrocarbon groups of the fatty acid of the monoglyceride is less than 8, adsorptivity on a metal surface will be weak and there will be little reducing effect on the resulting abrasion coefficient. Moreover, when the number of carbons of the hydrocarbon group of the fatty acid of the monoglyceride exceeds 22, solubility in the lubricating oil base oil will be weak and practical utility will suffer. Specific examples of hydrocarbon groups having 8

to 22 carbons are alkyl groups such as octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, eicosyl, heneicosyl, and docosyl groups (These alkyl groups can be linear or branched), and alkenyl groups such as octenyl, nonenyl, decenyl, undecenyl, dodecenyl, tridecenyl, tetradecenyl, pentadecenyl, hexadecenyl, heptadecenyl, octadecenyl, nonadecenyl, eicosenyl, heneicosenyl, and docosenyl groups. (These alkenyl groups can be linear or branched, and the position of the double bond can be an artibrary position and can be the cis or trans form).

Moreover, although the hydroxyl value of the monoglcyeride depends on the number of carbon atoms in the hydrocarbon group of the fatty acid, when the number of carbons is within a range of 8 to 22 as described above, it is ideally 150 to 350 mgKOH/g on the basis of the method for determining the hydroxyl groups value by JIS K0070. When the hydroxyl group value is lower than 150 mgKOH/g, solubility is high, but adsorptivity on a metal is low and there is little abrasion coefficient-lowering effect. When the hydroxyl group value is greater than 350 mgKOH/g, adsorptivity is strong, but solubility is weak and the product cannot stand up to practical use. It should be noted that ideally, the hydroxyl value is 200 to 350 mgKOH/g, preferably 220 to 330 mgKOH/g.

Furthermore, the monoglyceride content is, in terms of the total amount of composition, 0.3 to 2.0 mass%, preferably 0.4 to 1.7 mass%, more preferably 0.5 to 1.5 mass%.

Fatty Acid Ester and Derivative Thereof

As was previously mentioned, the lubricating oil

composition according to the present embodiment comprises a specific fatty acid ester or a fatty acid ester derivative wherein a polyoxyethylene is added to a fatty acid ester (referred to hereafter as "fatty acid ester, and the like"). Moreover, the fatty acid ester and the like in the present invention has an HLB value as calculated by any formulae therefor of 1.0 to 4.0. The method for calculating the HLB in the present invention is the Griffin method devised by Griffin of the US company Atlas. Refer to, for instance, "Surfactant Manual" (Sanyo Kasei Co., Ltd., Fujimoto Takehiko, June, 2007, edition 1, p. 142) for the details of the Griffin method. The HLB value (hydrophile-lipophile balance value) is the ratio of hydrophilic and lipophilic groups, and is generally found by the Griffin method, Oda method, or Davis method. The HLB of nonionic surfactants such as polyethylene glycol-type and polyhydric alcohols is calculated by the Griffin method ("Surfactant Manual" (Sanyo Kasei Co., Ltd., Fujimoto Takehiko, June 2007, edition 1, p. 142)).

Nonionic surfactant HLB = (hydrophilic group moiety molecular weight/surfactant molecular weight) × 20

Moreover, the HLB of the fatty acid ester of a polyhydric alcohol, which is one type of nonionic surfactant, can be calculated by the following formula.

Fatty acid ester HLB value = 20 × (1-S/A)

S: saponification value of the fatty acid ester [mgKOH/g]

A: acid value of fatty acid ester [mgKOH/g]

As mentioned previously, the lubricating oil composition relating to the present embodiment contains a monoglyceride having an excellent friction-reducing effect as an ash-free friction modifier, but the

monoglyceride has strong adsorptivity on metal surfaces. While strong adsorptivity on a metal surface is associated with the effect of lowering the abrasion coefficient by preventing metal-on-metal contact, it is estimated that there is a tendency toward the formation of an adsorption film at the interface between the water and oil (base oil). Therefore, a lubricating oil composition containing a monoglyceride will have strong anti-emulsification performance and water separation performance and when used in an internal combustion engine, the water of condensation from the water vapor generated by combustion of fuel will tend to precipitate at the metal surface of the engine parts when it mixes in the oil. The precipitated water contains oxidized combustion residue, and this residue can induce corrosion and rusting at the metal surface of the engine parts.

In order to improve the above-mentioned anti-emulsion performance and water separation performance of the lubricating oil composition, it is necessary to change the balance between hydrophilicity and lipophilicity and therefore, another surfactant must be added. However, precautions must be taken such that the added surfactant does not have a detrimental effect on the friction and friction-reducing effect (energy efficiency) of the lubricating oil composition.

Therefore, according to the present embodiment, it is possible to impart the water-encapsulating (emulsion retention) strength appropriate for a lubricating oil composition without impacting the friction-reducing effect of the monoglyceride, which is the ash-free friction modifier, or reducing the antiwear performance of the lubricating oil composition, by adding an

aliphatic acid ester having an HLB of 1.0 to 4.0 to the lubricating oil composition containing a monoglyceride, and thereby improve anti-emulsion performance and water separation performance and further improve rust resistance and corrosion resistance.

The fatty acid ester used in the present embodiment having the above-mentioned effect is a fatty acid ester wherein fatty acid forms an ester bond with at least one hydroxyl group of a compound having hydroxyl groups, such as an alcohol or sugar, and is not particularly restricted as long as the HLB value is within a range of 1.0 to 4.0. However, the following are specific examples of compounds having hydroxyl groups and fatty acids.

Examples of compounds having hydroxyl groups are methanol, ethanol, propanol, isopropyl alcohol, butanol, hexanol, octanol, 2-ethyl-hexyl alcohol, ethylene glycol, propylene glycol, trimethylol propane, pentaerythritol, sorbitan, sorbitol, polyethylene glycol, and polypropylene glycol.

Examples of fatty acids are caprylic acid, capric acid lauric acid, myristic acid, palmitic acid, stearic acid, behenic acid, oleic acid, 12-hydroxylstearic acid, erucic acid, linoleic acid, and α-linoleic acid.

Of the above-mentioned fatty acid esters, sorbitan fatty acid ester is the preferred fatty acid ester in terms of having an HLB within a range of 1.0 to 4.0 and having stronger ability to encapsulate water. Here, the sorbitan fatty acid ester is relatively soluble in the lubricating oil, easy to obtain, and has strong adsorptivity on a metal surface because it appropriately has intramolecular hydroxyl groups. Consequently, by adding the sorbitan fatty acid ester to the lubricating

oil composition, the sorbitan fatty acid ester will easily dissolve in the lubricating oil and a friction-reducing effect and oily effect can be easily obtained. In addition, there will not be a detrimental effect on the antiwear performance or the abrasion coefficient-lowering effect (energy efficiency) of the monoglyceride contained in the lubricating oil composition of the present embodiment.

In addition, for the same reason, a fatty acid triester is preferred wherein the compound having the hydroxyl groups is sorbitan. Furthermore, a sorbitan fatty acid triester that satisfies the above-mentioned conditions is particularly preferred as the fatty acid ester relating to the present embodiment.

The HLB value of the fatty acid ester, and the like used in the present invention must be 1.0 to 4.0, as previously explained, but in terms of obtaining better water-encapsulating strength (emulsion retention), the HLB is preferably 1.0 to 3.8, further preferably 1.0 to 3.5.

The content of fatty acid ester and the like is 0.7 mass% in terms of the total amount of lubricating oil composition. When the content of fatty acid ester, and the like is less than 0.7 mass%, water-encapsulating strength (emulsion retention) is insufficient and there is a chance that the water present in the lubricating oil composition will separate. In terms of stronger water-encapsulating strength, the content of fatty acid ester, and the like is 0.8 mass% or greater, preferably 0.9 mass% or greater. On the other hand, when the content of fatty acid ester, and the like is too high, there is a chance that adsorption of the antiwear additive will be

negatively impacted and there will be a reduction in antiwear performance. The content of fatty acid ester, and the like is preferably 2.0 mass% or less.

Other Arbitrary Components

In addition to the above-mentioned components, a variety of additives can be used as necessary in order to further improve the performance of the lubricating oil composition. Examples of such additives are pour point depressants, antioxidants, metal deactivators, anti-wear agents, antifoaming agents, viscosity index-improving agents, detergent dispersants, anti-rust agents, and the like, as well as other conventional lubricating oil additives.

Pour Point Depressant

A pour point depressant can be added in order to improve the low-temperature fluidity of the lubricating oil composition of the present embodiments. The pour point depressant is not particularly restricted, and for instance, the above-mentioned polymethacrylate polymer functions as a pour point depressant. The amount of pour point depressant added can be within a range of 0.01 to 5 parts by mass per 100 parts by mass of base oil.

Anti-Oxidant

An antioxidant that is used in lubricating oils is preferred for practical utility in the present embodiment. Examples are amine-based antioxidants, sulfur-based antioxidants, phenol-based antioxidants, and phosphorus-based antioxidants. One or a combination of multiple antioxidants can be used within a range of 0.01 to 5 parts by mass per 100 part by mass of the base oil.

Examples of the amine-based antioxidant are dialkyl-diphenylamines such as p,p'-dioctyl-diphenylamine (Seiko

Chemical Co., Ltd.: Nonflex OD-3), p,p-di-α-methylbenzyl-diphenylamine, and N-p-butylphenyl-N-p'-octylphenylamine; monoalkyldiphenylamines such as mono-t-butyldiphenylamine and monooctyldiphenylamine; bis(dialkylphenyl)amines such as di(2,4-diethylphenyl)amine and di(2-ethyl-4-nonylphenyl) amine; alkylphenyl-1-naphthylamines, such as octylphenyl-1-naphthylamine and N-ti-dodecylphenyl-1-naphthylamine; aryl-naphthylamines, such as 1-naphthylamine, phenyl-1-naphthylamine, phenyl-2-naphthylamine, N-hexylphenyl-2-naphthylamine, and N-octylphenyl-2-naphthylamine; phenylenediamines, such as N,N'-diisopropyl-p-phenylenediamine and N,N'-diphenyl-p-phenylenediamine; and phenoxthiazines such as phenothiazine (Hodogaya Co., Ltd.: Phenothiazine), and 3,7-dioctylphenothiazine.

Examples of sulfur-based antioxidants are dialkylsulfides, such as didodecylsulfide and dioctadecylsulfide; thiodiproponic acid esters, such as dodecylthiodipropionate, dioctadecylthiodipropionate, dimyristylthiodipropionate, and dodecyloctadecylthiodipropionate; and 2-mercaptobenzoimidazole.

Examples of phenol-based antioxidants are 2-t-butylphenol, 2-t-butyl-4-methylphenol, 2-t-butyl-5-methylphenol, 2,4-di-t-butylphenol, 2,4-dimethyl-6-t-butylphenol, 2-t-butyl-4-methoxyphenol, 3-t-butyl-4-methoxyphenol, 2,5-di-t-butylhydroquinone (Kawaguchi Chemical Co., Ltd.: Antage DBH), 2,6-di-t-butyl-4-alkylphenols such as 2,6-di-t-butylphenol, 2,6-di-t-butyl-4-methylphenol and 2,6-di-t-butyl-4-ethylphenol, and 2,6-di-t-butyl-4-alkoxyphenols such as 2,6-di-t-butyl-4-methoxyphenol and 2,6-di-t-butyl-4-ethoxyphenol.

Other phenol-based antioxidants are 3,5-di-t-butyl-4-hydroxybenzylmercapto-octylacetate; alkyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionates such as n-octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenl)propionate (Yoshitomi Seiyaku Co., Ltd., Yoshinox SS), n-dodecyl-3-(3,5-di-t-butyl-4-hydroxyphenol)propionate, 2'-ethylhexyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate, and benzene propionic acid 3,5-bis(1,1-dimethyl-ethyl)-4-hydroxy-C7-C9 side chain alkyl ester (Ciba Specialty Chemicals: Irganox L135); 2,6-di-t-butyl-α-dimethylamino-p-cresol, and 2,2'-methylenebis(4-alkyl-6-t-butylphenol), such as 2,2'-methylenebis(4-methyl-6-t-butylphenol (Kawaguchi Chemical Co., Ltd.: Antage W-400) and 2,2'-methylenebis(4-ethyl-6-t-butylphenol (Kawaguchi Chemical Co., Ltd.: Antage W-500).

Other examples are bisphenols, such as 4,4'-butylidenebis(3-methyl-6-t-butylphenol (Kawaguchi Chemical Co., Ltd.: Antage W-300), 4,4'-methylenebis(2,6-di-t-butylphenol) Shell Japan: Ionox 220AH), 4,4'-bis(2,6-di-t-butylphenol), 2,2-(di-p-hydroxyphenyl)propane Shell Japan: Bisphenol A), 2,2-bis(3,5-di-t-butyl-4-hydroxyphenyl)propane, 4,4'-cyclohexylidenebis(2,6-t-butylphenol),hexamethyleneglycolbis[3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate[(Ciba Specialty Chemicals: Irganox L109), triethylene glycol bis[3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionate] Yoshitomi Seiyaku Co., Ltd.: Tominox (917), 2,2'-thio[diethyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate (Ciba Specialty Chemicals: Irganox L115), 3,9-bis{1,1-dimethyl-2-[3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionyloxy]ethyl}2,4,8,10-tetraoxasprio[5,5]undecane (Sumitomo Kagaku: Sumilizer

GA80), and 4,4′-thiobis(3-methyl-6-t-butylphenol (Kawaguchi Chemical Co., Ltd.: Antage RC), and 2,2′-thiobis(4,6-di-t-butyl-resorinol).

Yet other phenol-based antioxidants include polyphenols such as such as tetrakis[methylene-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate]methane (Ciba Specialty Chemicals: Irganox L101), 1,1,3-tris(2-methyl-4-hydroxy-5-t-butylphenyl)butane (Yoshitomi Seiyaku Co., Ltd.: Yoshinox 930), 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-hydroxybenzyl)benzene (Shell Japan: Ionox 330), bis-[3,3′-bis-(4-‘-hydroxy-3′-t-butylphenyl)butyric acid]glycol ester, 2-(3′, 5′-di-t-butyl-4-hydroxyphenyl)methyl-4-(2″, 4″-di-t-butyl-3″-hydroxyphenyl)methyl-6-t-butylphenol, and 2,6-bis(2′-hydroxy-3′-t-butyl-5′-methyl-benzyl)-4-methylphenol, and phenol aldehyde condensates such as p-t-butylphenol and formaldehyde condensate and p-t-butylphenol and acetaldehyde condensates.

Examples of phosphorus-based antioxidants are triarylphosphites such as triphenylphosphite and tricresylphosphite; trialkylphosphate such as trioctadecylphosphate and tridecylphosphate; and tridodecyltrithiophospate.

The amount of sulfur-based and phosphorus-based antioxidants must be restricted taking into consideration the effect on the exhaust gas control system of the internal combustion engine. The lubricating oil should overall have a phosphorus content of 0.10 mass% or less and a sulfur content of 0.6 mass% or less, preferably a phosphorus content of 0.08 mass% or less and a sulfur content of 0.5 mass% or less.

Metal Deactivator

Examples of metal deactivators that can be used in combination with the composition relating to the present embodiment are benzotriazole; benzotriazole derivatives including 4-alkyl-benzotriazoles such as 4-methyl-benzotriazole and 4-ethyl-benzotriazole, 5-alkyl-benzotriazoles such as 5-methyl-benzotriazole and 5-ethyl-benzotriazole, 1-alkyl-benzotriazoles such as 1-dioctylaminomethyl-2,3-benzotriazole, and 1-alkyl-true triazoles such as 1-dioctylaminomethyl-2,3-true triazole; benzoimidazole; and benzoimidazole derivatives, including 2-(alkyldithio-benzoimidazoles such as 2-(octyldithio)-benzoimidazole, 2-(decyldithio)benzoimidazole, and 2-(dodecyldithio)benzoimidazole and 2-(alkyldithio)true imidazoles such as (2-(octyldithio)-true imidazole, 2-(decyldithio)true imidazole, and 2-(dodecyldithio)true imidazole.

Other examples of metal deactivators include indazole; indazole derivatives such as 4-alkylindazole, 5-alkylimdazole, and other true indazoles; benzothiazole; and benzothiazole derivatives such as 2-mercpatobenzothiazole derivatives (Chiyoda Chemical Co., Ltd. Thiorite B-3100), 2-(hexyldithio)benzothiazole, (2-octyldithio)benzothiazoles, and other 2-(alkyldithio)benzothiazoles, 2-(hexyldithio)true thiazole, 2-(octyldithio)true thiazole, and other 2-(alkyldithio)true thiazoles, 2-(N,N-diethyldithiocarbamyl)benzothiazole, 2-(N,N-dibutyldithiocarbamyl)-benzothiazole, 2-(N,N-dihexyldithiocarbamyl)benzothiaole, and other 2-(N, N-dialkyldithiocarbamyl)benzothiazoles, and 2-(N,N-diethyldithiocarbamyl) trithiazole, 2-(N,N-dibutyldithiocarbamyl)true thiazole, 2-(N,N-

dihexyldithocarbamyl)true thiazole, and other 2-(N,N-dialkyldithiocarbamyl) true thiazoles.

Yet other examples of metal deactivators are benzothiazole derivatives, including 2-(octyldithio)benzooxazole, 2-(decyldithio)benzooxazole, 2-(dodecyldithio)benzooxazoles, and other 2-(alkyldithio)benzooxazoles and 2-(octyldithio)trioxazole, 2-(decyldithio)true oxazole, 2-(dodecyldithio)true oxazole, and other 2-(alkyldithio)true oxazoles; thiazole derivatives such as 2,5-bis(heptyldithio)-1,3,4-thiadiazole, 2,5-bis(nonyldithio)-1,3,4-thiadizaole, 2,5-bis(dodecyldithio)-1,3,4-thiadiazole, 2,5-bis(octadecyldithio)-1,3,4-thiadiazole, and other 2,5-bis(alkyldithio)-1,3,4-thiadiazoles, 2,5-bis(N,N-diethyldithiocarbamyl)-1,3,4-thiadiazole, 2,5-bis(N,N-dibutyldithiocarbamyl)-1,3,4-thiadiazole, 2,5-bis(N,N-dioctyldithiocarbamyl)-1,3,4-thiadiazole, and other 2,5-bis(N,N-dialkyldithiocarbamyl)-1,3,4-thiadiazoles, and 2-N,N-dibutyldithocarbamyl-5-mercapto-1,3,4-thidiazole, 2-N,N-dioctyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole, and other 2-N,N-dialkyldithiocarbamyl-5-meercapto-1,3-4-thiadiazoles;; and triazole derivatives such as 1-di-octylaminomethyl-2,4-triazole and other 1-alkyl-2,4-triazoles. One or multiple metal deactivators can be used within a range of 0.01 to 0.5 parts by mass per 100 parts by mass of base oil.

Antiwear Agents

A phosphorus agent can also be added as an antiwear agent to the lubricating oil composition of the present embodiment in order to impart antiwear performance. Zinc dithiophosphate and zinc phosphate are examples of antiwear agents. These phosphorus compounds are added at

0.01 to 2 mass% per 100 parts by mass of base oil, and the phosphorus content in terms of total lubricating oil is preferably 0.05 to 0.10 mass%, more preferably 0.05 to 0.08 mass%. One or a combination of antiwear agents can be added. When the phosphorus content in terms of the total lubricating oil is 0.10 mass% or higher, there can be a detrimental effect on the catalyst of the exhaust gas control system, and the like, while when the phosphorus content is 0.05 mass% or less, antiwear performance as an engine oil cannot be expected.

Examples of zinc dithiophosphates are zinc dialkyldithiophosphate, zinc diaryldithiophosphate, and zinc arylalkyldithiophosphate. The hydrocarbon groups can be from alkyl groups such as C3-12 primary or secondary alkyl groups and the aryl groups can be from phenyl groups or alkylaryl groups wherein the phenyl groups are substituted by C1-18 alkyl groups.

Of these zinc dithiophosphates, zinc dialkyldithiophosphate having secondary alkyl groups are preferred. The number of carbons is 3 to 12, preferably 3 to 8, more preferably 3 to 6.

Antifoaming Agents

A antifoaming agent can be added to the lubricating oil composition of the present invention in order to impart anti-foaming performance. Examples are organosilicates such as dimethyl polysiloxane, diethyl silicate, and fluorosilicone and silicone-free antifoaming agents such as polyalkyl acrylate. The amount added is 0.0001 to 0.1 parts by mass per 100 parts by mass. One or multiple antifoaming agents can be added.

Lubricating Oil Composition – Properties

Viscosity of the lubricating oil composition

relating to the present invention is not particularly restricted, but the viscosity index is 100 or greater, preferably 110 or greater, further preferably 120 or greater, and the upper limit of the viscosity index is 300. The dynamic viscosity at 100°C of the lubricating oil composition is 5.6 to 15 mm2/s, preferably 5.6 to 12.5 mm2/s, more preferably 5.6 to 11.0 mm2/s.

Lubricating Oil Composition – Uses

The lubricating oil composition relating to the present embodiment is used as a lubricating oil composition for an internal combustion engine. The lubricating oil composition relating to the present embodiment can be used in an internal combustion engine that uses fuel having an H/C ratio of 1.75 to 4 (preferably 1.80 to 4, more preferably 1.93 to 4, further preferably 2.67 to 4). The commercial premium gasoline and regular gasoline H/C (carbon hydrogen ratio) is 1.763 and 1.875. When 3% of this premium gasoline and regular gasoline is substituted with (bio)ethanol, and the like, the H/C becomes 1.80 and 1.91, respectively. The H/C of "BASE," which is the equivalent of commercial No. 2 diesel fuel, is 1.91, and the H/C of diesel fuel JIS No. 2 is 1.927. When 5% of these diesel fuels are substituted with methyl stearate as a typical biodiesel fuel, the H/C increases to approximately 1.93. Examples of fuels having an H/C ratio of 1.75 to 4 are commercial premium gasoline, regular gasoline, premium gasoline and regular gasoline 3% of which has been substituted by (bio)ethanol (to realize an H/C of 1.80 and 1.91), diesel fuel JIS No. 2 5% of which has been substituted with biodiesel fuel such as fuel substituted by methyl stearate (H/C = 1.93), propane (H/C = 2.6), and natural

gas (H/C = 4 when methane is the primary ingredient). Moreover, the lubricating oil composition of the present embodiment can be used in the internal combustion engine of a vehicle having an idling stop device. Furthermore, the lubricating oil composition relating to the present invention is ideal for an internal combustion engine that uses fuel to which has been added biofuel (such as bioethanol, ethyl-tert-butyl ether, or cellulose ethanol) or biodiesel fuel (such as hydrogenated oil obtained by cracking and purification of crude oils and fats, including fatty acid methyl esters, plant oils, and animal fats, using petroleum hydrocracking technology, or synthetic oils obtained by synthesizing liquid hydrocarbons from biomass pyrolysis gases based on a catalytic reaction between carbon monoxide and hydrogen by the FT (Fischer-Tropsch) process). In particular, the lubricating oil composition relating to the present invention is ideal for use in an internal combustion engine that uses fuel to which more than 3 vol%, preferably 5 vol% or more, further preferably 10 vol% or more, has been added. In particular, the lubricating oil composition relating to the present embodiment is ideal for an internal combustion engine that uses fuel to which more than 5 mass%, preferably 7 mass% or more, further preferably 10 mass% or more has been added.

Examples

The lubricating oil composition for an internal combustion engine of the present invention has excellent antiwear performance and fuel efficiency (low-friction properties) and has the property of causing the water of condensation, and the like from the water vapor generated by fuel consumption to disperse in the oil and thereby

preventing corrosion and rusting of the internal combustion engine. The present invention will now be explain in specific terms using examples and comparative examples, but is in no way limited to these examples and comparative examples.

1. Ingredients

The following ingredients were used to prepare the examples and comparative examples.

Base Oil

Base oils 1 through 4 used in the examples and comparative examples have the properties in Table 1. Here, dynamic viscosity at 40°C and dynamic viscosity at 100°C are the values obtained by JIS K 2283 "Crude oil and petroleum products: Method for determining dynamic viscosity and method for calculating viscosity index." Moreover, the viscosity index is the value obtained in accordance with JIS K 2283 "Crude oil and petroleum products: Method for determining dynamic viscosity and method for calculating viscosity index." Furthermore, the pour point (P.P) was determined in accordance with JIS K 2269, the flash point was determined in accordance with JIS K 2265-4 (COC: Cleveland open cup method), the sulfur content was determined in accordance with JIS K 2541 (radiation excitation), and the %CA, %CN, and %CP were determined in accordance with ASTMD 3238. It should be noted that base oil 4 is a base oil that was produced from GTL (gas to liquid) wax synthesized by the Fischer-Tropsch method.

Additives

Additive A: Monoglyceride

The properties of the monoglyceride additive in the examples are shown below. The monoglyceride used in the

present example had the following properties.

Glycerin monooleate in the form of a white paste at a temperature of 25°C

Melting point of 41°C

Flash point (COC) of 220°C

Acid value of less than 1.0 mgKOH/g

Hydroxyl group value of 222 mgKOH/g

Additive B: Viscosity Index-Improving Agent

The viscosity index-improving agent that was added in the examples and comparative examples is shown below. The molecular weight was determined using the Showa Denko high-performance chromatograph Shodex GPC-101 under conditions of a temperature of 40°C, a differential refractive index detector (RI), a carrier gas flow rate of THF-1.0 mL/min (Ref 0.3 mL/min), a sample injection volume of 100 µL, and a {KF-G (Shodex) × 1, KF-805L (Shodex × 2)} column. The peak molecular weight was within a range of 2,600 to 690,000, and the average molecular weight (in terms of polystyrene) was analyzed (calculated).

Weight-average molecular weight (Mw): 283,000

Number-average molecular weight (Mn): 269,000

Mw/Mn = 1.05 nondispersing-type polymethacrylate (PMA) polymer

Additive C: ILSAC GF-5 Package Additive

Additive C is an additive package for internal combustion engine lubricating oil and comprises an antiwear agent, a dispersant, a metal detergent, an antioxidant, a metal deactivator, and the like. The Oronite product catalog states that when 8.9 to 10.55 mass% of this additive is added to lubricating oil, properties conforming with API-SN and ILSACGF-5

regulations are obtained. Consequently, in the examples, the amount of this additive C was 9.05 mass% in order to conform to the ILSAC GF-5 regulations. However, the amount of additive C is not particularly restricted.

Additive D: Antifoaming Agent Solution

The antifoaming agent solution was obtained by dissolving 3 mass% of dimethylpolysiloxane-type silicone oil to diesel fuel.

Additive E: Fatty Acid Ester, And The Like

The fatty acid ester or derivative thereof (surfactant) used as an additive in the examples and comparative examples, the HLB, and the product name are shown below. It should be noted that the numbers in parentheses are the HLB values.

Sorbitan trioleate (1.8): Rheodol SP-O30V (Kao Corporation)

Sorbitan tristearate (2.1): Rheodol SP-S30 (Kao Corporation)

Sorbitan monooleate (4.3): Rheodol SP-O10V (Kao Corporation)

Sorbitan monolaurate (8.6): Rheodol SP-L10 (Kao Corporation)

Polyoxyethylene (POE) sorbitan monooleate (10.0): Rheodol TW-O106V (Kao Corporation)

Polyoxyethylene (POE) sorbitan monolaurate (13.3): Rheodol TW-L106 (Kao Corporation)

2. Preparation of Lubricating Oil Composition

The lubricating oil composition for an internal combustion engine according to Examples 1 through 5 and Comparative Examples 1 through 11 shown in Table 2 were prepared using the above-mentioned components.

3. Tests

Each of the following texts were conducted in order to examine the performance of the lubricating compositions in Examples 1 through 5 and Comparative Examples 1 through 11.

(1) Anti-Emulsification Test

In order to evaluate the emulsification stability (water-encapsulating capability) of the lubricating oil, emulsification tests were conducted in accordance with ASTM D7563.

Using a commercial high-speed blender, such as Waring Blender 7011H (currently 7011S) that uses a stainless steel vessel made by MFI, the evaluation test was performed with trial-produced E85 fuel and distilled water. The test procedure is described below.

185 mL of the test oil to be evaluated was measured out using a 200 ml graduated cylinder under room temperature (20°C ± 5°C) and introduced to the 7011H blender. Then 15 mL of the trial-produced E85 fuel was measured out with a 100 mL graduated cylinder and introduced to the 7011H. Finally, 15 mL of distilled water was measured out with a 100 mL graduated cylinder and this was introduced to the 7011H. The vessel was immediately sealed and the contents were stirred for 60 seconds at 15,000 rpm. Once stirring was completed, 100 mL of the solution was introduced to a 100 mL graduated cylinder with a glass stopper and set aside for 24 hours in a thermostatic cell at a temperature of -5 to 0°C or 20 to 25°C. Once the cylinder had been kept in the thermostatic cell for 24 hours after stirring, the volume of oil-emulsion-water was measured using the scale on the graduated cylinder. Table 2 indicates that water separation was observed by "water separation" and that water separation was not

observed by "no water separation."

A mixture that was uniform at room temperature and was obtained by using a graduated cylinder to measure out 150 mL of commercial JIS1 automobile gasoline and 850 mL of special grade ethanol made by Wako Pure Chemicals served as trial-produced E85 fuel.

The mixing necessary for the test was completed in a predetermined short amount of time. The fuel was introduced to a container that could be firmly sealed such that the light components would not evaporate and stored in a cool dark place indoors.

(2) Shell Four-Ball Abrasion Test

A Shell four-ball abrasion test was conducted under conditions of 1,800 rpm, oil temperature of 50°C, load of 40 kgf, and time of 30 minutes in accordance with ASTM D 4172. After the test, the sample piece was removed and the amount of wear was determined.

(3) Abrasion Coefficient Determination Test

In order to examine abrasion properties, the abrasion coefficient was determined using the Cameron-Plint Te77 tester in accordance with ASTM-G-133 (American Society for Testing and Materials). The top test piece was a cylinder made of SK-3 having a diameter of 6 mm and length of 16 mm. The bottom test piece was a sheet made of SK-3. The test temperature was 80°C, load was 300 N, amplitude was 15 mm, the number of back-and-forth vibrations was 10 Hz and the test time was 10 minutes. The table shows average abrasion coefficient as determined the final minute after stabilization. The wear-reducing performance improves with a smaller abrasion coefficient.

(4) Results and discussion

Table 2 shows the results of performing the above-mentioned tests on Examples 1 through 5 and Comparative Examples 1 through 11.

Comparative Example 1 was an engine oil that did not contain glycerin monooleate. Separation of water was not observed in anti-emulsification tests. However, because Comparative Example 1 did not contain glycerin monooleate, the results of the abrasion coefficient determination tests were high at a wear damage diameter of 0.42 mm and abrasion coefficient of 0.112. Energy efficiency as a result of a reduction in engine friction was not obtained.

Comparative Example 2 contained glycerin monooleate. Therefore, wear damage diameter was 0.35 mm and the abrasion coefficient was less than 0.10. These were smaller than when glycerin monooleate was not added. The oil was energy efficient due to a reduction in the abrasion coefficient. However, it was obvious that due to the surfactant effect of the glycerin monooleate, water had separated in anti-emulsion testing of Comparative Example 2 at 25°C.

In Comparative Examples 3 through 5, a fatty acid ester, and the like (surfactant) having a low HLB of 4.0 or less was used. However, the concentration was 0.5 mass% or less and according to anti-emulsification tests at 25°C, water did separate. These results indicate that even when a fatty acid ester having an HLB of 4.0 or less is added, when the content is less than 0.7 mass%, there is little improving effect on anti-emulsification performance and water separating performance and sufficient water encapsulation (emulsification stability) is not obtained. It should be noted that in Comparative Examples 3 through 5, the abrasive wear diameter was 0.37

mm or less and the abrasion coefficient was less than 0.10, which as in Comparative Example 2, were smaller than when glycerin monooleate was not added, and energy efficiency due to a reduction in the abrasion coefficient was obtained.

In Comparative Examples 6 through 9, a fatty acid ester and the like having an HLB of 4.3 and 8.6 was used, but water encapsulation was weak and water separated when the concentration was either low at 0.5 mass% or high at 0.9 mass%. This indicates that even when a fatty acid ester and the like having an HLB exceeding 4.0 is added, the improving effect on anti-emulsification performance and water separation performance is weak and sufficient water encapsulation (emulsification stability) is not realized. It should be noted that in Comparative Examples 6 through 9, as in Comparative Example 2, the wear damage diameter at 0.36 mm or less and the abrasion coefficient at less than 0.10 were less than when glycerin monooleate was not added. Therefore, these comparative examples obtain an energy efficient effect due to a reduction in the abrasion coefficient.

In Comparative Examples 10 and 11, a fatty acid ester and the like having an HLB of 10.0 or greater was used, but in this case, water separated in the anti-emulsification tests at 0°C and 25°C and the water was not encapsulated in the lubricating oil. It should be noted that in Comparative Examples 10 and 11, as in Comparative Example 2, the wear damage diameter at 0.38 mm or less a the abrasion coefficient at least than 0.10 were less than when glycerin monooleate was not added and an energy efficient effect due to a reduction in the abrasion coefficient was obtained.

In Examples 1, 2, 3, and 4, a base oil belonging to API base oil Group 3 having a small sulfur content and small degree of unsaturation was used. In this case, as long as 0.7 mass% or more of fatty acid ester and the like having an HLB within a range of 1.0 to 4.0 is added, water separation performance is eliminated by the strong surface active effect of the monoglyceride and water encapsulation (emulsion retention) can be improved. Moreover, even when the above-mentioned fatty acid ester and the like is added, these properties and effects are retained without interfering with the antiwear performance and abrasion coefficient-lowering effect of the monoglyceride.

In Example 5, of the API Group 3 base oils, GTL (gas to liquid) base oil synthesized by the Fischer-Trosch method, and API Group 2 base oil were used. Even when these base oils are used, antiwear performance and an abrasion coefficient-lowering effect are maintained, water separation is eliminated, and water-encapsulating ability (emulsion retention) can be improved as long as 0.7 mass% or more of fatty acid ester and the like having an HLB within a range of 1.0 to 4.0 is added.

Table 1

		Base oil 1	Base oil 2	Base oil 3	Base oil 4
Base oil group (API classification)		Group 3	Group 3	Group 2	Group 3
Dynamic viscosity (JIS K2283) @ 100 0°C	mm2/sec	4.2	7.6	3.1	5.0
@ 40 0°C	mm2/sec	19.4	45.6	12.4	23.7
Viscosity coefficient (JIS K2283)		123	133	104	146
Pour point (JIS K2269)	0C	-15.0	-12.5	-32.5	-20.0
Ignition point (JIS K2265, COC)	0C	214	240	194	232
Sulfur content (JIS K2541; radiation-type excitation method)	mass%	0.0008	0.0010	<0.01	<0.01
ATSM D3238-95	%CA	0	0	0	0
	%CN	22.4	20.4	31.1	7
	%CP	77.6	79.6	69.9	93

Table 2

Component	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Base oil 1 mass%	72.71	71.81	71.51	71.31	71.31
Base oil 2 mass%	12.00	12.00	12.00	12.00	12.00
Base oil 3 mass%					
Base oil 4 mass%					
GF-5 package additive mass%	9.05	9.05	9.05	9.05	9.05
Viscosity index improver mass%	6.20	6.20	6.20	6.20	6.20
Anti-foaming solution mass%	0.04	0.04	0.04	0.04	0.04
Monoglyceride mass%		0.90	0.90	0.90	0.90
Fatty acid ester (HLB) mass% Sorbitan triooleate (1.8 Sorbitan tristearate (2.1) Sorbitan monooleate (4.3 Sorbitan Monolaurate (8.6) POE sorbitan monooleate (10.0) POE sorbitan monolaurate (13.3)			0.30	0.50	0.50
Total Mass%	100.00	100.00	100.00	100.00	100.00
Anti-emulsification test (4˚C, 24hr)					

Oil mass% Emulsion mass% Water mass%	0 100 0	0 100 0	0 100 0	0 100 0	0 100 0
Anti-emulsification test (25°C, 24hr)					
Oil mass% Emulsion mass% Water mass%	78 22 0	86 2 12	88 0 12	35 59 6	60 35 5
Water separation	No water separation	Water separation	Water separation	Water separation	Water separation
Shell 4-ball abrasion test (1800rpm x 40hgf x 30min x 50°C) Abrasion damage diameter mm	0.42	0.35	0.37	0.35	0.35
Abrasion coefficient test (300N x 80°C x 10Hz x 15mm) Abrasion coefficient	0.112	0.096	0.097	0.095	0.93

Table 2 (Continued)

Component	Comparative Example 6	Comparative Example 7	Comparative Example 8	Comparative Example 9	Comparative Example 10
Base oil 1 mass%	71.31	70.91	71.31	70.91	71.31
Base oil 2 mass%	12.00	12.00	12.00	12.00	12.00
Base oil 3 mass%					
Base oil 4 mass%					
GF-5 package additive mass%	9.05	9.05	9.05	9.05	9.05
Viscosity index improver mass%	6.20	6.20	6.20	6.20	6.20
Anti-foaming solution mass%	0.04	0.04	0.04	0.04	0.04
Monoglyceride mass%	0.90	0.90	0.90	0.90	0.90
Fatty acid ester (HLB) mass% Sorbitan triooleate (1.8 Sorbitan tristearate (2.1) Sorbitan monooleate (4.3) Sorbitan Monolaurate (8.6) POE sorbitan monooleate (10.0) POE sorbitan monolaurate (13.3)	0.50	0.90	0.50	0.90	0.50
Total Mass%	100.00	100.00	100.00	100.00	100.00
Anti-emulsification test (4°C, 24hr)					

Oil mass% Emulsion mass% Water mass%	0 100 0	0 100 0	90 0 10	95 0 5	86 0 14
Anti-emulsification test (25°C, 24hr)					
Oil mass% Emulsion mass% Water mass%	60 30 10	40 50 10	86 0 14	87 0 13	86 0 14
Water separation	Water separation	Water separation	Water separation	Water separation	Water separation
Shell 4-ball abrasion test (1800rpm x 40hgf x 30min x 50°C) Abrasion damage diameter mm	0.36	0.36	0.35	0.35	0.36
Abrasion coefficient test (300N x 80°C x 10Hz x 15 mm) Abrasion coefficient	0.095	0.094	0.096	0.095	0.096

Table 2 (Continued)

Component	Comparative Example 11	Example 1	Example 2	Example 3	Example 4
Base oil 1 mass%	71.31	71.11	70.91	71.11	70.91
Base oil 2 mass%	12.00	12.00	12.00	12.00	12.00
Base oil 3 mass%					
Base oil 4 mass%					
GF-5 package additive mass%	9.05	9.05	9.05	9.05	9.05
Viscosity index improver mass%	6.20	6.20	6.20	6.20	6.20
Anti-foaming solution mass%	0.04	0.04	0.04	0.04	0.04
Monoglyceride mass%	0.90	0.90	0.90	0.90	0.90
Fatty acid ester (HLB) mass% Sorbitan triooleate (1.8 Sorbitan tristearate (2.1) Sorbitan monooleate (4.3 Sorbitan Monolaurate (8.6) POE sorbitan monooleate (10.0) POE sorbitan monolaurate (13.3)	0.50	0.70	0.90	0.70	0.90
Total Mass%	100.00	100.00	100.00	100.00	100.00
Anti-emulsification test (4°C, 24hr)					

Oil mass% Emulsion mass% Water mass%	86 0 14	0 100 0	0 100 0	0 100 0	0 100 0
Anti-emulsification test (25°C, 24hr)					
Oil mass% Emulsion mass% Water mass%	86 0 14	30 70 0	20 80 0	50 50 0	30 70 0
Water separation	Water separation	No water separation	No water separation	No water separation	No water separation
Shell 4-ball abrasion test (1800rpm x 40hgf x 30min x 50°C) Abrasion damage diameter mm	0.38	0.37	0.35	0.35	0.34
Abrasion coefficient test (300N x 80°C 10Hz x 15mm) Abrasion coefficient	0.098	0.092	0.092	0.094	0.093

Table 2 (Continued)

Component	Example 5
Base oil 1 mass%	
Base oil 2 mass%	
Base oil 3 mass%	15.67
Base oil 4 mass%	67.24
GF-5 package additive mass%	9.05
Viscosity index improver mass%	6.20
Anti-foaming solution mass%	0.04
Monoglyceride mass%	0.90
Fatty acid ester (HLB) mass% Sorbitan triooleate (1.8 Sorbitan tristearate (2.1) Sorbitan monooleate (4.3 Sorbitan Monolaurate (8.6) POE sorbitan monooleate (10.0) POE sorbitan monolaurate (13.3)	0.90
Total Mass%	100.00
Anti-emulsification test (4°C, 24hr)	
Oil mass% Emulsion mass% Water mass%	0 100 0

Anti-emulsification test (25°C, 24hr)	
Oil mass% Emulsion mass% Water mass%	25 75 0
Water separation	No water separation
Shell 4-ball abrasion test (1800rpm x 40hgf x 30min x 50°C) Abrasion damage diameter mm	0.34
Abrasion coefficient test (300N x 80°C x 10Hz x 15mm) Abrasion coefficient	0.092

The above-mentioned has been a description of the preferred embodiment of the present invention, but the present invention is not restricted to the above-mentioned embodiment. That is, other embodiments and various modifications conceivable by a person skilled in the art and within the scope of the invention as cited in the claims falls under the technical scope of the present invention.

C L A I M S

1. A lubricating oil composition for an internal combustion engine comprising:

(a) at least one base oil selected from the group consisting of base oils classified as Group 2, 3, or 4 by API (US Petroleum Institute) base oil category and showing a dynamic viscosity at 100°C of 3.0 to 12.0 mm^2/s,

(b) a monoglyceride having C_8-C_{22} carbohydrate groups and a hydroxyl value of 150 to 350 mgKOH/g, in an amount of 0.3 to 2.0 mass% in terms of the total amount of composition, and

(c) a fatty acid ester having an HLB value of 1.0 to 4.0, or a fatty acid ester derivative wherein polyoxyethylene has been added to this fatty acid ester, in an amount that is at least 0.7 mass% based on the total amount of composition.

2. The lubricating oil composition according to claim 1, characterized in that the lubricating oil composition is used in an internal combustion engine that uses fuel having an H/C ratio of 1.75 to 4, an internal combustion engine of a vehicle with an idling stop device, or an internal combustion engine that uses a fuel to which a biofuel or a biodiesel fuel has been added.

3. The lubricating oil composition according to claim 1 or 2, characterized in that the fatty acid ester is a sorbitan fatty acid ester.

4. The lubricating oil composition according to any one of claims 1 to 3, characterized in that the fatty acid ester is a fatty acid triester.

5. The lubricating oil composition according to any one

of claims 1 to 4 wherein the base oil is present at a level of from 50 mass% to 90 mass%, based on the total amount of composition.

6. The lubricating oil composition according to any one of claims 1 to 5 wherein the monoglyceride is present at a level of from 0.4 to 1.7 mass%, based on the total amount of composition.

7. The lubricating oil composition according to any one of claims 1 to 6 wherein the content of fatty acid ester or fatty acid ester derivative is 0.8 mass% or greater, based on the total amount of composition.

8. The lubricating oil composition according to any one of claims 1 to 7 wherein the content of fatty acid ester or fatty acid ester derivative is 0.9 mass% or greater, based on the total amount of composition.

9. The lubricating oil composition according to any one or claims 1 to 8 wherein the content of fatty acid ester of fatty acid ester derivative is 2 mass% or less, based on the total amount of composition.

10. Use of a lubricating composition according to any of claims 1 to 9 for reducing engine corrosion.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/060127

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10M129/76
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10M C10N

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 953 214 A1 (NISSAN MOTOR [JP]) 6 August 2008 (2008-08-06)	1-9
Y	paragraph [0121] - paragraph [0123]; example 7; table 1 paragraphs [0001], [0014], [0019] - paragraph [0020]	10

Y	US 2011/263470 A1 (QIN HAIHU [US] ET AL) 27 October 2011 (2011-10-27)	10
A	paragraphs [0002], [0004], [0111], [0151] - paragraph [0153]; claims 17,18 paragraph [0197] - paragraph [0198]	1-9

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 July 2014	09/07/2014

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/060127

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