

[DESCRIPTION]

[Title]

LUBRICATING OIL COMPOSITION

[Field]

**[0001]**

The present invention relates to a lubricating oil composition. More particularly, the present invention relates to a lubricating oil composition which is excellent in metal fatigue life, wear resistance and electrical insulating properties, even when the composition has a reduced viscosity, and which is suitable for a gear or a transmission for use in an automobile.

[Background]

**[0002]**

Lubricating oil compositions for use in automobiles are needed to have a reduced viscosity, for the purpose of saving fuel. However, merely reducing the viscosity of conventional lubricating oil compositions leads to the occurrence of metal fatigue or wear at the surfaces of gear teeth or in bearings. Although various investigations have been done in order to reduce the viscosity of lubricating oil compositions for use in automobiles, a reduction in the viscosity adversely affect the ability to form an oil film on the sliding surfaces, causing a deterioration in metal fatigue life, wear resistance, electrical insulating properties and the like. Accordingly, there has been a lower limit to which the viscosity of lubricating oil compositions can be reduced. For example, Japanese Unexamined Patent Publication (Kokai) No. 2010-059374 (PTL 1) discloses a technique in which a reduction in the viscosity is achieved by using a hydrogenated saturated polydiene to which a functional group is introduced. However, the resulting lubricating oil composition has a kinematic viscosity at 100°C of about from 5 to 14 mm<sup>2</sup>/s, which is not sufficient to meet the fuel saving performance needed at the moment. Further, Japanese Translation of PCT International Application Publication No. JP-T-H11-506391 (PTL 2) and Japanese Translation of PCT International Application Publication No. JP-T-H11-506978 (PTL 3) disclose lubricating oil compositions containing an unsaturated polydiene to which a functional group is introduced. However, these disclosures are silent about solving the above described problems associated with achieving fuel saving.

[Citation List]

[Patent Literature]

**[0003]**

[PTL 1] Japanese Unexamined Patent Publication (Kokai) No. 2010-059374

[PTL 2] Japanese Translation of PCT International Application Publication No. JP-T-H11-506391

[PTL 3] Japanese Translation of PCT International Application Publication No. JP-T-H11-506978

[Summary]

[Technical Problem]

**[0004]**

In view of the above mentioned problems, an object of the present invention is to provide a lubricating oil composition which has a viscosity much lower than that of a conventional lubricating oil composition, and which is excellent in metal fatigue life, wear resistance and electrical insulating properties.

[Solution to Problem]

**[0005]**

The present inventors have found out that, by incorporating a specific polydiene and by not incorporating a viscosity index improver to a lubricating oil composition, it is possible to provide a lubricating oil composition having a kinematic viscosity at 100°C of not less than 1 and less than 5 mm<sup>2</sup>/s, and nevertheless, to maintain excellent metal fatigue life, wear resistance and electrical insulating properties of the composition.

**[0006]**

In other words, the present invention relates to a lubricating oil composition, which comprises:

(A) a lubricating base oil; and

(B) from 0.6 to 4.0% by weight, based on the total weight of the lubricating oil composition, of a polydiene having a number average molecular weight of from 500 to 3,000 and containing a functional group on at least one end thereof,

wherein the lubricating oil composition does not comprise a viscosity index improver, and wherein the lubricating oil composition has a kinematic viscosity at 100°C of not less than 1 and less than 5 mm<sup>2</sup>/s.

**[0007]**

More preferably, the present invention provides the lubricating oil composition satisfying at least one of following (1) to (11).

(1) The functional group in component (B) is selected from a carboxyl group, ester group, anhydrous carboxyl group, hydroxyl group, glycidyl group, and amino group.

(2) The functional group is a hydroxyl group.

(3) The lubricating oil composition further comprises (C) at least one selected from a phosphorus-based anti-wear agent and a phosphorus-based extreme pressure agent.

(4) The phosphorus-based anti-wear agent (C) is a zinc dialkyldithiophosphate.

(5) The phosphorus-based extreme pressure agent (C) is at least one selected from the group consisting of a phosphoric acid ester, a phosphorous acid ester, a thiophosphoric acid ester, a thiophosphorous acid ester, an acidic phosphoric acid ester, an acidic phosphorous acid ester, a acidic thiophosphoric acid ester and a acidic thiophosphorous acid ester, and an amine salt thereof.

(6) The lubricating oil composition further comprises (D) a sulfur-based extreme pressure agent.

(7) The lubricating oil composition further comprises (E) an ashless dispersant.

(8) The lubricating base oil (A) has a kinematic viscosity at 100°C of from 1 to 4 mm<sup>2</sup>/s.

(9) The lubricating oil composition is a gear oil for use in an automobile.

(10) The lubricating oil composition is a transmission oil for use in an automobile.

(11) The lubricating oil composition is a transmission oil for use in a hybrid vehicle.

#### [Advantageous Effects of Invention]

##### [0008]

The present invention can provide a lubricating oil composition which has a viscosity lower than that of a conventional lubricating oil composition, and which is excellent in metal fatigue life, wear resistance and electrical insulating properties. The lubricating oil composition according to the present invention is suitably used as a gear oil for use in an automobile, a transmission oil for use in an automobile, or a transmission oil for use in a hybrid vehicle.

#### [Description of Embodiments]

##### [0009]

One of the characteristics of the lubricating oil composition according to the present invention is that the composition does not contain a viscosity index improver. Conventional lubricating oil compositions generally contain a viscosity index improver in order to improve viscosity characteristics. For example, a viscosity index improver such as polymethacrylate, polyisobutylene or a hydrogenated product thereof, a styrene-diene hydrogenated copolymer, a styrene-maleic anhydride ester copolymer, or a polyalkylstyrene has been used. However, the incorporation of such a viscosity index improver results in an increase in the kinematic viscosity, and accordingly, there has been a limit to which the viscosity of a lubricating oil composition can be reduced. The present invention aims to further reduce the viscosity of a lubricating oil

composition by not incorporating the viscosity index improver to the composition, and has enabled to provide a lubricating oil composition having a kinematic viscosity at 100°C of not less than 1 and less than 5 mm<sup>2</sup>/s.

**[0010]**

The lubricating oil composition according to the present invention has a kinematic viscosity at 100°C of not less than 1 mm<sup>2</sup>/s and less than 5 mm<sup>2</sup>/s. The lubricating oil composition according to the present invention more preferably has a kinematic viscosity at 100°C of not less than 1.5 mm<sup>2</sup>/s and not more than 4.5 mm<sup>2</sup>/s, and most preferably not less than 1.5 mm<sup>2</sup>/s and not more than 4.0 mm<sup>2</sup>/s.

**[0011]**

(A) Lubricating Base Oil

The lubricating base oil in the present invention may be any conventionally known lubricating base oil, and may be a mineral oil, a synthetic oil, or a mixed oil thereof. The kinematic viscosity of the lubricating base oil is not limited, but the lubricating base oil preferably has a kinematic viscosity at 100°C of from 1 to 4 mm<sup>2</sup>/s.

**[0012]**

A mineral base oil may be, for example: a paraffin- or naphthene-based lubricating base oil, or the like, which is obtained by preparing a lubricating oil fraction by distillation of crude oil under normal pressure and/or reduced pressure, and then refining the lubricating oil fraction by combining, as appropriate, any of refining treatments such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrorefining, sulfuric acid washing, clay treatment, and the like; or a lubricating base oil obtained by isomerization and dewaxing of a wax obtained by solvent dewaxing. The kinematic viscosity of the mineral base oil is not particularly limited. However, in order to obtain a lubricating oil composition having a low viscosity, the mineral base oil preferably has a kinematic viscosity at 100°C of from 1 to 4 mm<sup>2</sup>/s.

**[0013]**

As a synthetic base oil, it is possible to use a poly- $\alpha$ -olefin, an  $\alpha$ -olefin copolymer, an isoparaffin, an alkylbenzene, an alkylnaphthalene, a monoester, a diester, a polyol ester, a polyoxyalkylene glycol, a dialkyl diphenyl ether, a polyphenyl ether, a GTL base oil, or the like. The kinematic viscosity of the synthetic base oil is not particularly limited. However, in order to obtain a lubricating oil composition having a low viscosity, the synthetic base oil preferably has a kinematic viscosity of from 1 to 4 mm<sup>2</sup>/s.

**[0014]**

One kind of lubricating base oil may be used alone, or two or more kinds thereof may be used in combination. In the case of using two or more kinds of lubricating base oils, the

lubricating base oils can be used: in a combination of two or more kinds of mineral base oils; in a combination of two or more kinds of synthetic base oils; or in a combination of one or more kinds of mineral base oils and one or more kinds of synthetic base oils.

**[0015]**

Further, in order to obtain a lubricating oil composition having a low viscosity, the lubricating base oil, as a whole, has a kinematic viscosity at 100°C of from 1 to 4 mm<sup>2</sup>/s, preferably from 1.5 to 3.5 mm<sup>2</sup>/s, and particularly preferably from 2 to 3.3 mm<sup>2</sup>/s.

**[0016]**

**(B) Polydiene Containing Functional Group on at Least One End Thereof**

Component (B) is a polydiene in which at least one end of the molecular chain is modified by introduction of a functional group (hereinafter, sometimes referred to as an “end-modified polydiene”). A polydiene is a polymer or copolymer produced by polymerization or copolymerization of a diene monomer(s), and a saturated polydiene is a hydrogenated product in which carbon-carbon double bonds of the polydiene obtained as described above are saturated by hydrogenation. The lubricating oil composition according to the present invention is characterized by comprising the end-modified polydiene. The end-modified polydiene may be an end-modified unsaturated polydiene or an end-modified saturated polydiene. From the viewpoint of improving the solubility in the lubricating base oil, it is preferable to use an end-modified saturated polydiene. The polydiene containing a functional group is adsorbed onto the sliding surface, and partially increases the viscosity of the composition, and thereby increases the thickness of the oil film of the lubricating oil composition. This allows for reducing the metal fatigue or wear at the surfaces of gear teeth or in the bearings, and for improving the ability of the composition to protect parts, when using a lubricating oil composition having a reduced viscosity.

**[0017]**

The end-modified saturated polydiene has a number average molecular weight of from 500 to 3,000. The end-modified saturated polydiene more preferably has a number average molecular weight of from 600 to 2,500, and most preferably from 800 to 2,000. Having a number average molecular weight of less than the above described lower limit value causes a decrease in the resistance to metal fatigue; whereas having a number average molecular weight exceeding the upper limit value leads to an increased thickening effect, thereby hindering fuel saving performance; both of which are problematic and thus not preferable. The value of the number average molecular weight is a value obtained by gel permeation chromatography (GPC), using polystyrene as a standard material.

**[0018]**

Examples of the diene monomer include hydrocarbons containing from 4 to 10 carbon

atoms and containing at least two unsaturated bonds. Specific examples thereof include: conjugated dienes such as 1,3-butadiene, isoprene, 2,3-dimethyl-1,3-butadiene, 1,3-pentadiene, 2-methyl-1,3-pentadiene, 1,3-hexadiene, 4,5-dimethyl-1,3-octadiene, 3-butyl-1,3-octadiene and chloroprene; and non-conjugated dienes such as 1,4-pentadiene, 1,5-hexadiene and 1,7-octadiene. From the viewpoint of providing an end-modified polydiene which is effective for extending the metal fatigue life, a preferable diene monomer is a conjugated diene, and a more preferred diene monomer is 1,3-butadiene or isoprene.

**[0019]**

The polydiene obtained by polymerization of such a diene monomer may have, in the case of polybutadiene, for example, a structure which can be obtained by 1,2-addition or by 1,4-addition. Further, the polydiene may have a structure resulting from both types of additions.

**[0020]**

The saturated polydiene in the present invention may be not only a polymer of the above diene monomer, but also a copolymer of the diene monomer and another monomer(s). The other monomer copolymerizable with such a diene monomer is preferably, for example, a vinyl aromatic hydrocarbon, and examples thereof include styrene,  $\alpha$ -methylstyrene, p-methylstyrene, divinylbenzene and t-butylstyrene.

**[0021]**

As described above, component (B) is a polydiene in which at least one end of the molecular chain is modified by introduction of a functional group. Component (B) may be a polydiene in which a functional group is introduced to only one end of the molecular chain, or a polydiene in which functional groups are introduced to both ends of the molecular chain. Further, in the case of a polydiene having a branched molecular chain, a functional group(s) may be introduced to the end(s) of the branch(es) of the polydiene. From the viewpoint of enhancing the effect of extending and maintaining the metal fatigue life, it is preferable that functional groups be introduced to at least both ends of the molecular chain.

**[0022]**

The functional group in the present invention may be, for example, a functional group containing at least one heteroatom selected from the group consisting of oxygen, sulfur, nitrogen and phosphorus. Examples of preferable functional groups include a carboxyl group, ester group, anhydrous carboxyl group, hydroxyl group, glycidyl group, urethane group and amino group. Among these, particularly preferable are carboxyl group, hydroxyl group, glycidyl group and amino group, and most preferable is hydroxyl group, from the viewpoint of improving the metal fatigue life.

**[0023]**

The average number of functional groups per one polydiene molecule is from 1 to 10,

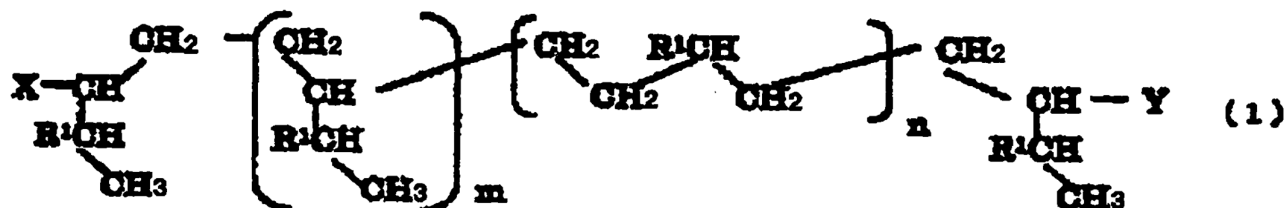
and preferably 1.5 or more. When the average number of functional groups is less than 1, the resulting lubricant oil composition has a markedly short metal fatigue life due to insufficient oil film formation; whereas when the average number of functional groups is more than 10, there is a risk of causing a decrease in solubility.

[0024]

As described above, a saturated polydiene is one in which carbon-carbon double bonds in its main chain are hydrogenated. The degree of hydrogenation can be determined by the level of iodine number or bromine number. It is preferable that the iodine number be 100 or less, or the bromine number be 63 or less, and at least one of the above needs to be satisfied. In particular, the iodine number is preferably 80 or less, and more preferably 20 or less. Having a low degree of hydrogenation is disadvantageous, because it results in a poor solubility in a base oil having a low polarity. It is to be noted that the hydrogenation is preferably carried out selectively at double bonds present in the main chain of the polydiene, and the hydrogenation of functional groups is preferably avoided. The iodine number and the bromine number can be measured in accordance with ASTM D 1959 and JIS K 2605, respectively.

[0025]

More specifically, the end-modified saturated polydiene may be, for example, a compound represented by following Formula (1):



In Formula (1), X represents a monovalent functional group; Y represents a hydrogen atom or a monovalent functional group. When Y is a hydrogen atom, the resulting polydiene is one in which a functional group is introduced to one end thereof; whereas when Y is a monovalent functional group, the resulting polydiene is one in which functional groups are introduced to both ends thereof. The monovalent functional group is as described above, and preferable examples thereof include a carboxyl group, hydroxyl group, anhydrous carboxyl group, ester group, amino group, and glycidyl group. Each  $\text{R}^1$  represents a monovalent hydrocarbon group containing from 1 to 6 carbon atoms. Each  $\text{R}^1$  is preferably a linear or branched aliphatic hydrocarbon group, and particularly preferably an alkyl group. m represents an integer of 0 or from 1 to 100, and preferably an integer of from 10 to 60; and n represents an integer of 0 or from 1 to 100, and preferably an integer of from 10 to 60. The above end-modified saturated polydiene can be selected and obtained as appropriate, from compatible products available on the market.

[0026]

The amount of component (B) to be incorporated in the lubricating oil composition according to the present invention is from 0.6 to 4.0% by weight, preferably from 0.8 to 3.8% by weight, and more preferably from 1.0 to 3.6% by weight, based on the total weight of the lubricating oil composition. An amount of component (B) of less than the above lower limit value results in an insufficient effect of improving the metal fatigue life. An amount of component (B) exceeding the above upper limit value is not preferable, since it rarely leads to an increase in the effect of improving the metal fatigue life, but may rather result in an increase in the viscosity, possibly causing adverse effects.

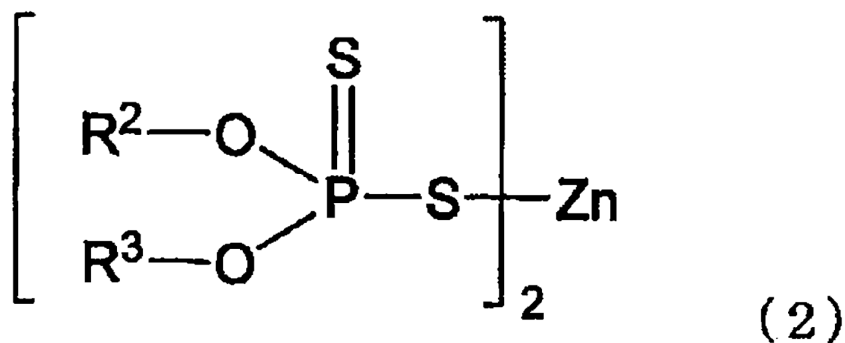
[0027]

(C) Phosphorus-based Anti-wear Agent or Phosphorus-based Extreme Pressure Agent

The lubricating oil composition according to the present invention preferably contains at least one selected from a phosphorus-based anti-wear agent and a phosphorus-based extreme pressure agent (hereinafter, sometimes referred to as a “phosphorus-based additive”). The amount of component (C) is preferably such that the total content of phosphorus atoms based on the total weight of the lubricating oil composition is from 50 to 500 ppm by weight, more preferably from 80 to 450 ppm by weight, still more preferably from 100 to 400 ppm by weight, and particularly preferably from 120 to 400 ppm by weight. By adjusting the amount of the phosphorus-based additive within the above range, it becomes possible to more securely maintain an excellent metal fatigue life, wear resistance and electrical insulating properties of the resulting lubricating oil composition, even when the composition has a reduced viscosity.

[0028]

The phosphorus-based anti-wear agent is not particularly limited, and may be any conventionally known compound which is known as an anti-wear agent for use in a lubricating oil composition. The phosphorus-based anti-wear agent may be, for example, a zinc dialkyldithiophosphate (ZnDTP (also referred to as ZDDP)). ZnDTP is represented by following Formula (2):



[0029]

In above Formula (2),  $R^2$  and  $R^3$  each independently represents a hydrogen atom or a monovalent hydrocarbon group containing from 1 to 26 carbon atoms. The monovalent hydrocarbon group is: a primary or secondary alkyl group containing from 1 to 26 carbon atoms; an alkenyl group containing from 2 to 26 carbon atoms; a cycloalkyl group containing from 6 to 26 carbon atoms; an aryl group, alkylaryl group or arylalkyl group containing from 6 to 26 carbon atoms; or a hydrocarbon group containing an ester bond, ether bond, alcohol group or carboxyl group. It is more preferable that  $R^2$  and  $R^3$  each independently represent a primary or secondary alkyl group containing from 2 to 12 carbon atoms, a cycloalkyl group containing from 8 to 18 carbon atoms, or an alkylaryl group containing from 8 to 18 carbon atoms. The phosphorus-based anti-wear agent is particularly preferably a zinc dialkyldithiophosphate. The primary alkyl group preferably contains from 3 to 12 carbon atoms, and more preferably from 4 to 10 carbon atoms. The secondary alkyl group preferably contains from 3 to 12 carbon atoms, and more preferably from 3 to 10 carbon atoms. Further, zinc dithiocarbamate (ZnDTC) may be used in combination. A zinc dialkyldithiophosphate containing a primary alkyl group (Pri-ZnDTP) and a zinc dialkyldithiophosphate containing a secondary alkyl group (Sec-ZnDTP) may be used singly, or in combination of two or more kinds thereof. In the case of using two or more kinds in combination, the mixing ratio thereof is not particularly limited.

**[0030]**

In the lubricating oil composition according to the present invention, the phosphorus-based anti-wear agent, particularly, a zinc dialkyldithiophosphate, may be contained in such an amount that the total amount of phosphorus atoms based on the total weight of the lubricating oil composition satisfies the above range. Specifically, the phosphorus-based anti-wear agent is contained in such an amount that the amount of phosphorus derived from the phosphorus-based anti-wear agent is from 50 to 500 ppm by weight, preferably from 80 to 450 ppm by weight, more preferably from 100 to 400 ppm by weight, and particularly preferably from 120 to 400 ppm by weight, based on the total weight of the lubricating oil composition. By incorporating the phosphorus-based anti-wear agent in such an amount that the amount of phosphorus in the composition is within the above range, it is possible to prevent a decrease in the metal fatigue life, and to secure the wear resistance and the electrical insulating properties, of the resulting lubricating oil composition.

**[0031]**

The phosphorus-based extreme pressure agent is not particularly limited, and may be any conventionally known compound which is known as an extreme pressure agent for use in a lubricating oil composition. The phosphorus-based extreme pressure agent is preferably at least one selected from the group consisting of: phosphoric acid, phosphorous acid, phosphonic acid, a phosphoric acid ester, a phosphorous acid ester, a thiophosphoric acid ester, a thiophosphorous

acid ester, an acidic phosphoric acid ester, an acidic phosphorous acid ester, a phosphonic acid ester, a acidic thiophosphoric acid ester and a acidic thiophosphorous acid ester, and an amine salt thereof. The phosphorus-based extreme pressure agent may contain sulfur. A phosphorus-sulfur-based extreme pressure agent, such as a thiophosphoric acid ester, is encompassed in the definition of the phosphorus-based extreme pressure agent, but not in the definition of the sulfur-based extreme pressure agent to be described later. It is to be noted, however, that zinc dithiophosphate is not encompassed in the definition of the phosphorus-based extreme pressure agent in the present invention. Particularly preferably, the phosphorus-based extreme pressure agent in the present invention does not contain a metal element.

**[0032]**

The phosphoric acid ester and the acidic phosphoric acid ester are represented by the formula:  $(R^4O)_aP(=O)(OH)_{3-a}$ . In the formula, a represents 0, 1, 2 or 3; and each  $R^4$  independently represents a monovalent hydrocarbon group containing from 4 to 30 carbon atoms. When a is 1 or 2, the compound represented by the formula:  $(R^4O)_aP(=O)(OH)_{3-a}$  is an acidic phosphoric acid ester.

**[0033]**

The phosphorous acid ester and the acidic phosphorous acid ester are represented by the formula:  $(R^4O)_bP(=O)(OH)_{2-b}H$ . In the formula, b represents 0, 1, or 2; and each  $R^4$  independently represents a monovalent hydrocarbon group containing from 4 to 30 carbon atoms.

**[0034]**

The phosphoric acid ester and the acidic phosphoric acid ester are preferably a monoalkyl phosphate, a dialkyl phosphate, or a trialkyl phosphate, but not limited thereto.

**[0035]**

The phosphorous acid ester and the acidic phosphorous acid ester are preferably a monoalkyl phosphite or a dialkyl phosphite, but not limited thereto.

**[0036]**

Further, the definition of phosphorus-based extreme pressure agent also encompasses a compound obtained by replacing some of oxygen atoms in the above phosphoric acid, phosphorous acid, phosphonic acid, phosphoric acid ester, phosphorous acid ester, phosphonic acid ester, acidic phosphoric acid ester or acidic phosphorous acid ester, with a sulfur atom(s), such as, for example, a thiophosphoric acid ester, a thiophosphorous acid ester, an acidic thiophosphoric acid ester, or an acidic thiophosphorous acid ester.

**[0037]**

More specific examples of the phosphorus-based extreme pressure agent include mono-octyl phosphate, di-octyl phosphate, tri-octyl phosphate, mono-octyl phosphite, di-octyl

phosphite, monooctyl thiophosphate, dioctyl thiophosphate, trioctyl thiophosphate, monooctyl thiophosphite, dioctyl thiophosphite, monododecyl phosphate, didodecyl phosphate, tridodecyl phosphate, monododecyl phosphite, didodecyl phosphite, acidic butyl phosphate, acidic hexyl phosphate, acidic octyl phosphate, acidic dodecyl phosphate, acidic butyl phosphite, acidic hexyl phosphite, acidic octyl phosphite and acidic dodecyl phosphite, but not limited thereto.

**[0038]**

Further, it is also possible to suitably use alkyl amine salts and alkenyl amine salts of the compounds which are partially esterified, among the above compounds. In other words, amine salts of acidic phosphoric acid esters and amine salts of acidic phosphorous acid esters can be used, but not limited thereto.

**[0039]**

More specific examples thereof include amine salts of monooctyl phosphate, amine salts of dioctyl phosphate, amine salts of trioctyl phosphate, amine salts of dioctyl phosphite, amine salts of trioctyl phosphite, amine salts of dioctyl thiophosphate, amine salts of trioctyl thiophosphate, amine salts of tridodecyl thiophosphate, amine salts of didecyl phosphate, amine salts of didecyl phosphite, amine salts of didodecyl phosphate, amine salts of tridodecyl phosphate, amine salts of didodecyl phosphite, amine salts of tridodecyl phosphite, amine salts of tridodecyl thiophosphate, amine salts of trihexadodecyl phosphate, amine salts of trihexadodecyl phosphite, amine salts of acidic butyl phosphite, amine salts of acidic hexyl phosphate, amine salts of acidic octyl phosphate, amine salts of acidic dodecyl phosphate, amine salts of acidic butyl phosphite, amine salts of acidic hexyl phosphite, amine salts of acidic octyl phosphite and amine salts of acidic dodecyl phosphite.

**[0040]**

As described above, the phosphorus-based extreme pressure agent is contained in such an amount that the total content of phosphorus atoms based on the total weight of the lubricating oil composition satisfies the above range. Specifically, the phosphorus-based extreme pressure agent is contained in such an amount that the amount of phosphorus atoms derived from the phosphorus-based extreme pressure agent is from 50 to 500 ppm by weight, preferably from 80 to 450 ppm by weight, more preferably from 100 to 400 ppm by weight, and particularly preferably from 120 to 400 ppm by weight, based on the total weight of the lubricating oil composition.

**[0041]**

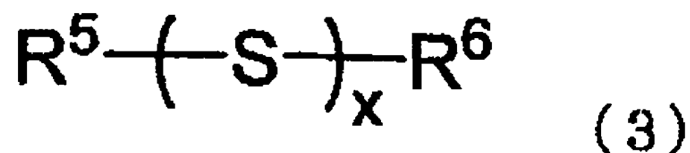
**(D) Sulfur-based Extreme Pressure Agent**

The lubricating oil composition according to the present invention may optionally further contain a sulfur-based extreme pressure agent. The sulfur-based extreme pressure agent may be any known compound, but is preferably at least one selected from sulfide compounds

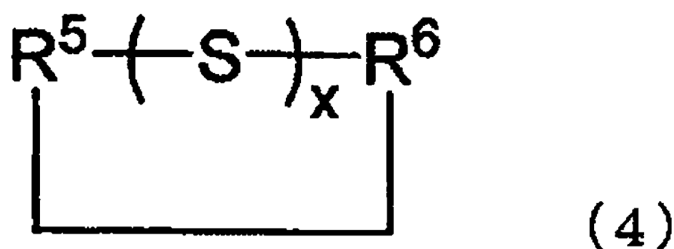
represented by sulfurized olefins, and sulfurized esters represented by sulfurized fats and oils. A sulfurized olefin is particularly preferable.

[0042]

The sulfur-based extreme pressure agent is represented, for example, by following General Formula (3):



In Formula (3),  $R^5$  and  $R^6$  each independently represents a monovalent substituent group containing at least one element selected from carbon, hydrogen, oxygen and sulfur atoms. The monovalent substituent group may be, for example, a linear or branched, saturated or unsaturated hydrocarbon group containing from 1 to 40 carbon atoms. The hydrocarbon group may be an aliphatic, aromatic, or araliphatic hydrocarbon group, and may contain an oxygen atom and/or a sulfur atom. Further,  $R^5$  and  $R^6$  may be bound to each other. When a compound represented by Formula (3) contains only one bond, the compound is represented, for example, by following General Formula (4):



[0043]

In each of above Formulae (3) and (4), x represents an integer of 1 or more, and preferably an integer of from 1 to 12. A smaller value of x tends to result in a decrease in extreme pressure properties; whereas too large a value of x tends to result in a decrease in thermal oxidative stability.

[0044]

Sulfurized olefins are obtained by sulfurization of olefins. Compounds including sulfurized olefins, and those obtained by sulfurization of hydrocarbon-based raw materials other than olefins, are collectively referred to as sulfide compounds. Examples of the sulfurized olefin include those obtained by sulfurizing olefins, such as polyisobutylenes and terpenes, with sulfur or other sulfurizing agents.

[0045]

Examples of the sulfide compound other than the sulfurized olefin include diisobutyl

disulfide, dioctyl polysulfide, di-tert-butyl polysulfide, diisobutyl polysulfide, dihexyl polysulfide, di-tert-nonyl polysulfide, didecyl polysulfide, didodecyl polysulfide, diisobutylene polysulfide, dioctenyl polysulfide, and dibenzyl polysulfide.

**[0046]**

Sulfurized fats and oils are reaction products of fats and oils with sulfur, and obtained by a sulfurization reaction of fats and oils, using animal and vegetable fats and oils such as lard, beef tallow, whale oil, palm oil, coconut oil and rapeseed oil. Such a reaction product does not consist of a single kind of substance, but is a mixture of various types of substances, and the chemical structure itself of the reaction product is not entirely clear.

**[0047]**

Examples of the sulfurized ester include, in addition to the sulfurized fats and oils described above, those obtained by: allowing various types of organic acids (such as saturated fatty acids, unsaturated fatty acids, dicarboxylic acids and aromatic carboxylic acids) to react with various types of alcohols to obtain ester compounds; and then sulfurizing the ester compounds with sulfur or other sulfurizing agents. As with the case of sulfurized fats and oils, the chemical structure itself of such a compound is not entirely clear.

**[0048]**

The amount of the sulfur-based extreme pressure agent according to the present invention is not limited. However, the sulfur-based extreme pressure agent is preferably contained in the lubricating oil composition in an amount of from 0.01 to 5% by weight, more preferably from 0.1 to 3% by weight, and still more preferably from 0.2 to 2% by weight.

**[0049]**

**(E) Ashless Dispersant**

The lubricant composition according to the present invention can further comprises an ashless dispersant. The ashless dispersant is not particularly limited, and any conventionally known compound may be used. The ashless dispersant may be, for example: a nitrogen-containing compound which contains, within the molecule, at least one linear or branched alkyl group or alkenyl group containing from 40 to 400 carbon atoms, or a derivative thereof; or succinimide or a modified product thereof. One kind of ashless dispersant may be used alone, or two or more kinds thereof may be used in combination. Further, it is also possible to use a boronated ashless dispersant. The boronated ashless dispersant is one obtained by boronating an arbitrary ashless dispersant used in a lubricating oil. Boronation is usually carried out by allowing an imide compound to react with boric acid, to neutralize some or all of the remaining amino groups and/or imino groups.

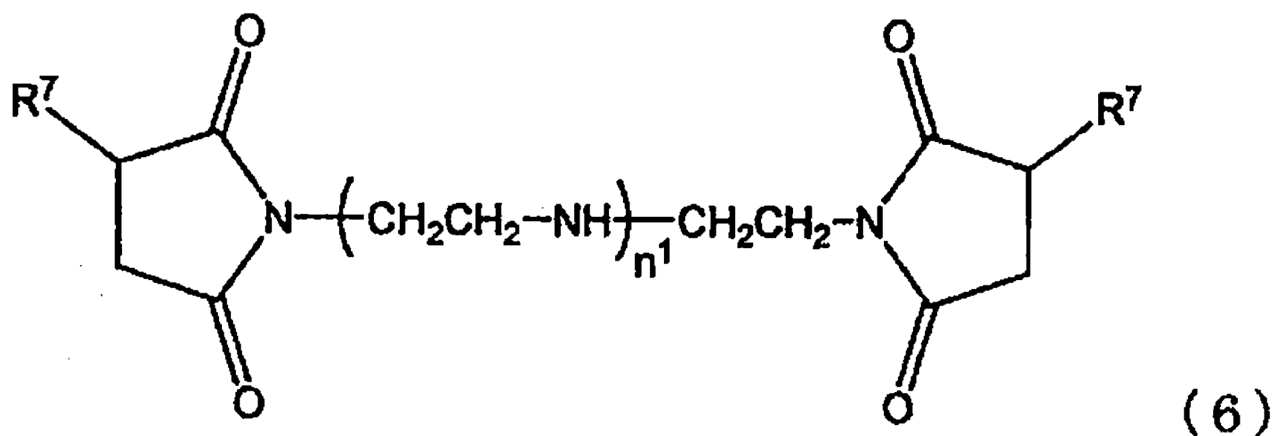
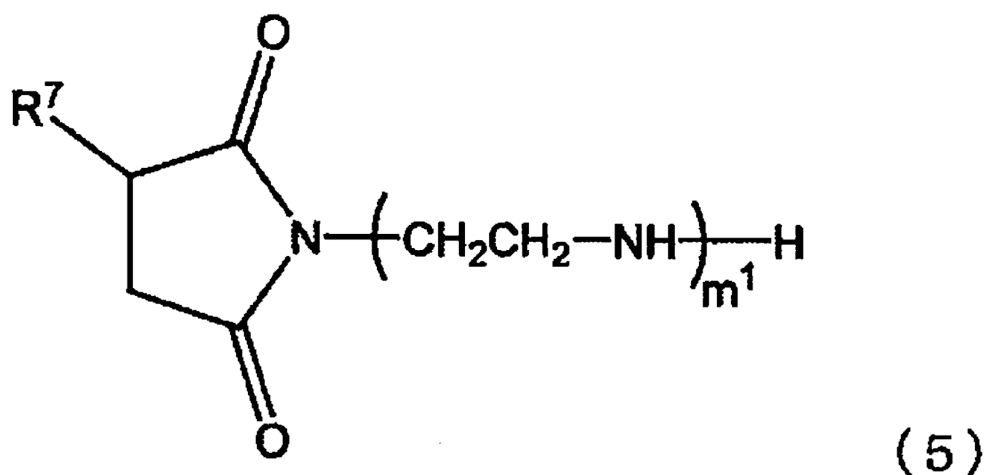
**[0050]**

The above alkyl group or alkenyl group preferably contains from 40 to 400 carbon atoms,

and more preferably from 60 to 350 carbon atoms. When the number of carbon atoms contained in the alkyl group or the alkenyl group is less than the above lower limit value, the solubility of the nitrogen-containing compound in the lubricating base oil tends to decrease. When the number of carbon atoms contained in the alkyl group or the alkenyl group exceeds the above upper limit value, the low temperature fluidity of the resulting lubricating oil composition tends to deteriorate. The alkyl group or the alkenyl group may have a linear structure or a branched structure. A preferable embodiment thereof may be, for example, a branched alkyl group or a branched alkenyl group derived from an oligomer of an olefin such as propylene, 1-butene or isobutene, or from a co-oligomer of ethylene and propylene.

**[0051]**

The succinimide is classified into two types: a so-called mono-type succinimide, which is a reaction product obtained by adding succinic anhydride to one end of a polyamine; and a so-called bis-type succinimide which is a reaction product obtained by adding succinic anhydride to both ends of a polyamine. The lubricating oil composition according to the present invention may comprise at least one of the mono-type and bis-type succinimides, or may contain both types of succinimides. The mono-type succinimide compound can be represented, for example, by following Formula (5). The bis-type succinimide compound can be represented, for example, by following Formula (6).



In the above formulae, each  $\text{R}^7$  independently represents an alkyl group or an alkenyl group containing from 40 to 400 carbon atoms;  $m^1$  represents an integer of from 1 to 20; and  $n^1$  represents an integer of from 0 to 20. In particular, a bis-type succinimide compound is preferable. As the succinimide compound, mono-type and bis-type compounds may be used in combination; or alternatively, two or more kinds of mono-type compounds, or two or more kinds of bis-type compounds may be used in combination.

[0052]

The modified product of succinimide refers, for example, to one obtained by modifying succinimide with a boron compound (hereinafter, sometimes referred to as a “boronated succinimide”). The expression “to modify with a boron compound” as used herein means “to boronate”. One kind of boronated succinimide may be used alone, or two or more kinds thereof may be used in combination. In the case of combined use, two or more kinds of boronated succinimides may be used in combination. Further, the lubricating oil composition according to the present invention may comprise both the mono-type and bis-type succinimides, or may comprise a combination of two or more kinds of mono-type succinimides, or a combination of

two or more kinds of bis-type succinimides. Boronated and non-boronated succinimides may also be used in combination.

**[0053]**

The boronated succinimide can be produced, for example, by any of methods disclosed in Japanese Examined Patent Publication (Kokoku) No. S42-8013 and Japanese Examined Patent Publication (Kokoku) No. S42-8014, Japanese Unexamined Patent Publication (Kokai) No. S51-52381, and Japanese Unexamined Patent Publication (Kokai) No. S51-130408. Specifically, the boronated succinimide can be obtained, for example, by mixing a polyamine and succinic anhydride (derivative) with a boron compound such as boric acid, a boric acid ester or a boric acid salt, in an alcohol, an organic solvent such as hexane or xylene, a light lubricating base oil or the like, followed by a heat treatment under an appropriate conditions. The boron content in the thus obtained boronated succinimide can usually be adjusted to from 0.1 to 4% by weight. In the present invention, a boron-modified compound of an alkenyl succinimide compound (boronated succinimide) is particularly preferable, because of its excellent heat resistance, anti-oxidative properties and anti-ware properties.

**[0054]**

The boron content in the boronated ashless dispersant is not particularly limited. The boron content is usually from 0.1 to 3% by weight based on the weight of the ashless dispersant. In one embodiment of the present invention, the boron content in the ashless dispersant is preferably 0.2% by weight or more, and more preferably 0.4% by weight or more; and at the same time, preferably 2.5% by weight or less, more preferably 2.3% by weight or less, and still more preferably 2.0% by weight or less. The boronated ashless dispersant is preferably a boronated succinimide, and particularly preferably a boronated bis-succinimide.

**[0055]**

The boronated ashless dispersant has a boron/nitrogen weight ratio (B/N ratio) of 0.1 or more, and preferably 0.2 or more; and at the same time, preferably less than 1.0, and more preferably 0.8 or less.

**[0056]**

The content of the ashless dispersant may be adjusted as appropriate. For example, the content is preferably from 0.01 to 20% by weight, and more preferably from 0.1 to 10% by weight, based on the total weight of the lubricating oil composition. A content of the ashless dispersant of less than the above lower limit value may result in insufficient sludge dispersibility. A content of the ashless dispersant exceeding the above upper limit value may cause a degradation of a specific rubber material, or a deterioration in the low temperature fluidity.

**[0057]**

To the lubricating oil composition according to the present invention, any of other

additives other than above components (A) to (E) can be added as appropriate, to the extent that the effect of the present invention is not impaired; however, a viscosity index improver (such as polymethacrylate, polyisobutylene or a hydrogenated product thereof, a styrene-diene hydrogenated copolymer, a styrene-maleic anhydride ester copolymer, or a polyalkylstyrene) is not added to the lubricating oil composition. Examples of the other additives include metal detergents, friction modifiers, oil agents, rust inhibitors, antioxidants, corrosion inhibitors, metal inactivating agents, pour point depressants, antifoaming agents, colorants, and additive packages for automatic transmission oils. It is also possible to add any of various types of lubricating oil additive packages containing at least one of the above additives.

**[0058]**

The lubricating oil composition in the present invention can be used, in particular, as a lubricating oil composition for use in an automobile, in which a low viscosity is preferable, and can be suitably used as a gear oil for use in an automobile or a transmission oil for use in an automobile. Further, the lubricating oil composition according to the present invention can provide a good friction-reducing effect. Accordingly, the lubricating oil composition can be used not only as a lubricating oil for an automatic transmission, but also as a transmission oil in which high friction-reducing properties are preferable, such as a transmission oil for use in a hybrid vehicle which does not include a clutch. The lubricating oil composition according to the present invention can be used in accordance with a conventionally known method, and optimized depending on the preferable performance.

[Examples]

**[0059]**

The present invention will now be described in detail, with reference to Examples and Comparative Examples. However, the present invention is in no way limited by the following Examples.

The base oil and additives to be used in the Examples are as described below.

(A) Lubricating Base Oil

A mineral oil (highly refined base oil, kinematic viscosity at 100°C: 3 mm<sup>2</sup>/s, viscosity index: 122; Group III base oil)

(B) Polydiene Compound

(B1) Saturated polybutene containing hydroxyl groups at both ends (number average molecular weight (Mn): 1,000)

(B2) Saturated polybutene containing hydroxyl groups at both ends (number average molecular weight (Mn): 3,000)

(B3) Saturated polybutene containing carboxyl groups at both ends (number average

molecular weight (Mn): 1,000)

(B4) Unsaturated polybutene containing hydroxyl groups at both ends (number average molecular weight (Mn): 1,000)

(B5) Saturated polybutene with unmodified ends (number average molecular weight (Mn): 3,000) (for comparison)

(B6) Saturated polybutene containing urethane groups at both ends (number average molecular weight (Mn): 1,000)

(C) Phosphorus-based Additive

A zinc dialkyldithiophosphate (anti-wear agent, secondary alkyl, 2-ethylhexyl group)

(D) Sulfur-based Extreme Pressure Agent

A sulfurized ester (sulfur content: 10% by weight)

(E) Ashless Dispersant

Polybutenyl succinic bisimide (molecular weight of polybutenyl group: 3,000, nitrogen content: 1.0% by weight, boron content: 0.5% by weight)

(F) Other Additives

An antioxidant (diphenylamine), a metal inactivating agent, and an antifoaming agent

(G) Viscosity Index Improver (for comparison)

Polymethacrylate (weight average molecular weight: 50,000, amount of polymer: 50% by weight)

**[0060]**

<Examples 1 to 5 and Comparative Examples 1 to 4>

The respective components described above are mixed at the compositions and amounts shown in Table 1, to obtain respective lubricating oil compositions of Examples and Comparative Examples.

The amounts of respective components shown in Tables will be described below.

The amount of the phosphorus-based extreme pressure agent is the amount of phosphorus based on the total amount of the lubricating oil composition, given in ppm by weight. The amounts of each polybutene, the sulfur-based extreme pressure agent, the dispersant, the viscosity index improver, and the other additives are each the amount thereof based on the total amount of the lubricating oil composition, given in % by weight. The amount of the base oil is the balance of the total amount of the lubricating oil composition, which is taken as 100.

**[0061]**

The properties of each of the lubricating oil compositions were evaluated as describe below.

(1) Kinematic viscosity (100°C) was measured in accordance with ATSM D445.

(2) Metal fatigue properties

Metal fatigue properties were measured by a unit test using a thrust needle bearing having an inner diameter of 19.2 mm, an outer diameter of 28.5 mm, and a needle diameter of 2 mm. The measurement was carried out at an additional thrust load of 10.5 N, a number of revolution of 3,000 rpm, and an oil temperature of 120°C, and the number of cycles until the occurrence of metal fatigue was counted.

(3) Wear resistance was measured in accordance with ASTM D4172-2.

(4) Electrical insulating properties (volume resistivity) were measured in accordance with JIS C2101.

(5) Solubility of a polydiene compound in a lubricating base oil

The solubility was evaluated as “○” when the resulting solution was transparent; the solubility was evaluated as “Δ”, when the resulting solution was not transparent, but it was possible to carry out the measurements of physical properties without problems; and the solubility was evaluated as “×”, when the resulting solution was clouded, and it was unable to carry out the measurements of physical properties.

It is to be noted that when the polydiene compound has a poor solubility, the measurements of other physical property values were not carried out. Further, when the lubricating oil composition has a kinematic viscosity at 100°C of more than 5 mm<sup>2</sup>/s, the measurements of other physical property values were not carried out, as well.

**[0062]**

Table 1-1

|             |                                                              | Example<br>1 | Example<br>2 | Example<br>3 | Example<br>4 | Example<br>5 |
|-------------|--------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|
| Composition | (B) Polybutene                                               |              |              |              |              |              |
|             |                                                              | 3            |              |              |              |              |
|             |                                                              |              | 3            |              |              |              |
|             |                                                              |              |              | 3            |              |              |
|             |                                                              |              |              |              | 3            |              |
|             |                                                              |              |              |              |              |              |
|             | (C) Phosphorus-based<br>extreme pressure agent               | 300          | 300          | 300          | 300          | 300          |
|             |                                                              |              |              |              |              |              |
|             |                                                              |              |              |              |              |              |
|             |                                                              |              |              |              |              |              |
| Evaluation  | (G) Viscosity index improver (polymethacrylate)              | 0            | 0            | 0            | 0            | 0            |
|             |                                                              | Balance      | Balance      | Balance      | Balance      | Balance      |
|             | (A) Lubricating base oil                                     |              |              |              |              |              |
|             | (D) Sulfur-based extreme pressure agent (a sulfurized ester) | 0.5          | 0.5          | 0.5          | 0.5          | 0.5          |
|             | (E) Ashless dispersant                                       | 4            | 4            | 4            | 4            | 4            |
|             | (F) Other additives                                          | 0.23         | 0.23         | 0.23         | 0.23         | 0.23         |
|             | Solubility                                                   | o            | o            | o            | o            | Δ            |
|             | Kinematic viscosity at 100°C (mm <sup>2</sup> /s)            | 4.2          | 4.2          | 4.2          | 4.2          | 4.2          |
|             | Metal fatigue properties (megacycle)                         | 59.8         | 50.2         | 61.9         | 74.2         | 63.4         |
|             | Wear resistance (mm)                                         | 0.43         | 0.43         | 0.43         | 0.41         | 0.42         |
|             | Electrical insulating properties (10 <sup>9</sup> Ω · cm)    | 6.2          | 6.1          | 6.2          | 6.3          | 6.2          |

Table 1-2

|             |                                                                          | Comparative<br>Example 1 | Comparative<br>Example 2 | Comparative<br>Example 3 | Comparative<br>Example 4 |
|-------------|--------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Composition | (B1) Saturated polybutene containing OH groups at both ends, Mn: 1,000   | 0.5                      | 5                        |                          | 3                        |
|             | (B2) Saturated polybutene containing OH groups at both ends, Mn: 3,000   |                          |                          |                          |                          |
|             | (B3) Saturated polybutene containing COOH groups at both ends, Mn: 1,000 |                          |                          |                          |                          |
|             | (B4) Unsaturated polybutene containing OH groups at both ends, Mn: 1,000 |                          |                          |                          |                          |
|             | (B5) Saturated polybutene with unmodified ends, Mn: 3,000                |                          |                          | 3                        |                          |
|             | (B6) Polybutene containing urethane groups at both ends, Mn: 1,000       |                          |                          |                          |                          |
|             | (C) Phosphorus-based extreme pressure agent                              | 300                      | 300                      | 300                      | 300                      |
|             | (G) Viscosity index improver (polymethacrylate)                          | 0                        | 0                        | 0                        | 5                        |
|             | (A) Lubricating base oil                                                 | Balance                  | Balance                  | Balance                  | Balance                  |
|             | (D) Sulfur-based extreme pressure agent (a sulfurized ester)             | 0.5                      | 0.5                      | 0.5                      | 0.5                      |
| Evaluation  | (E) Ashless dispersant                                                   | 4                        | 4                        | 4                        | 4                        |
|             | (F) Other additives                                                      | 0.23                     | 0.23                     | 0.23                     | 0.23                     |
|             | Solubility                                                               | o                        | x                        | o                        | o                        |
|             | Kinematic viscosity at 100°C (mm <sup>2</sup> /s)                        | 3.9                      |                          | 4.2                      | 5.2                      |
|             | Metal fatigue properties (megacycle)                                     | 48.2                     | -                        | 47.0                     | -                        |
|             | Wear resistance (mm)                                                     | 0.46                     | -                        | 0.70                     |                          |
|             | Electrical insulating properties (10 <sup>9</sup> Ω · cm)                | 6.2                      | -                        | 6.1                      |                          |

**[0063]**

As shown in Table 1, each of the lubricating oil compositions of Examples 1 to 5 has a kinematic viscosity at 100°C of not less than 1 and less than 5 mm<sup>2</sup>/s, metal fatigue properties of 50 megacycles or more, a wear resistance of 0.5 mm or less, and electrical insulating properties (volume resistivity) of  $6.0 \times 10^9 \Omega \cdot \text{cm}$  or more. In other words, each of the lubricating oil compositions according to the present invention is capable of exhibiting excellent metal fatigue properties and wear resistance, as well as good electrical insulating properties (volume resistivity), at a kinematic viscosity at 100°C of less than 5 mm<sup>2</sup>/s. Further, each end-modified polydiene compound used exhibited a good solubility in the lubricating base oil.

In contrast, as can be seen from the results of Comparative Example 1, an insufficient amount of the specific polydiene compound added results in poor metal fatigue properties. As can be seen from the results of Comparative Example 3, the use of the polydiene compound with unmodified ends results in poor metal fatigue properties and wear resistance. These results reveal that each of the lubricating oil compositions of Comparative Examples 1 and 3 is poor in any of metal fatigue properties, wear resistance and electrical insulating properties. Further, the lubricating oil composition of Comparative Example 2 has a problem in solubility. Still further, as can be seen from the results of Comparative Example 4, the lubricating oil composition containing the viscosity index improver has a kinematic viscosity at 100°C of more than 5 mm<sup>2</sup>/s. Since a reduction in viscosity intended in the present invention was not achieved in the lubricating oil composition of Comparative Example 4, the measurements of other respective physical property values were not carried out.

**[Industrial Applicability]****[0064]**

The lubricating oil composition according to the present invention satisfies all of the metal fatigue properties, wear resistance and electrical insulating properties, despite having a reduced viscosity. Accordingly, the lubricating oil composition is particularly suitable as a transmission oil or a gear oil, and above all, as a transmission oil for use in a hybrid vehicle.

[CLAIMS]

[Claim 1]

A lubricating oil composition, comprising:

(A) a lubricating base oil; and

(B) from 0.6 to 4.0% by weight, based on the total weight of the lubricating oil composition, of a polydiene having a number average molecular weight of from 500 to 3,000 and containing a functional group on at least one end thereof,

wherein the lubricating oil composition does not comprise a viscosity index improver, and wherein the lubricating oil composition has a kinematic viscosity at 100°C of not less than 1 and less than 5 mm<sup>2</sup>/s.

[Claim 2]

The lubricating oil composition according to claim 1, wherein the functional group in component (B) is selected from a carboxyl group, ester group, anhydrous carboxyl group, hydroxyl group, glycidyl group, urethane group and amino group.

[Claim 3]

The lubricating oil composition according to claim 2, wherein the functional group is a hydroxyl group.

[Claim 4]

The lubricating oil composition according to any one of claims 1 to 3, further comprising (C) at least one selected from a phosphorus-based anti-wear agent and a phosphorus-based extreme pressure agent.

[Claim 5]

The lubricating oil composition according to claim 4, wherein the phosphorus-based anti-wear agent is a zinc dialkyldithiophosphate.

[Claim 6]

The lubricating oil composition according to claim 5, wherein the phosphorus-based extreme pressure agent is at least one selected from the group consisting of a phosphoric acid ester, a phosphorous acid ester, a thiophosphoric acid ester, a thiophosphorous acid ester, an acidic phosphoric acid ester, an acidic phosphorous acid ester, a acidic thiophosphoric acid ester and a acidic thiophosphorous acid ester, and an amine salt thereof.

[Claim 7]

The lubricating oil composition according to any one of claims 1 to 6, further comprising (D) a sulfur-based extreme pressure agent.

[Claim 8]

The lubricating oil composition according to any one of claims 1 to 7, further comprising (E) an ashless dispersant.

[Claim 9]

The lubricating oil composition according to any one of claims 1 to 8, wherein the lubricating base oil (A) has a kinematic viscosity at 100°C of from 1 to 4 mm<sup>2</sup>/s.

[Claim 10]

The lubricating oil composition according to any one of claims 1 to 9, which is a gear oil for use in an automobile.

[Claim 11]

The lubricating oil composition according to any one of claims 1 to 9, which is a transmission oil for use in an automobile.

[Claim 12]

The lubricating oil composition according to claim 11, which is a transmission oil for use in a hybrid vehicle.