US 20140256607A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2014/0256607 A1

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(43) Pub. Date: Sep. 11, 2014

(54) LUBRICATION OIL COMPOSITION

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(21) Appl. No.: **14/353,405**

(22) PCT Filed: **Oct. 24, 2012**

(86) PCT No.: **PCT/JP2012/077480**

§ 371 (c)(1), (2), (4) Date: **Apr. 22, 2014**

(30) **Foreign Application Priority Data**

Oct. 28, 2011 (JP) 2011-238007

Publication Classification

(51) **Int. Cl.**

C10M 105/40 (2006.01)
C10M 105/36 (2006.01)
C10M 105/18 (2006.01)

(52) **U.S. Cl.**

CPC ***C10M 105/40*** (2013.01); ***C10M 105/18*** (2013.01); ***C10M 105/36*** (2013.01); *C10M 2203/003* (2013.01); *C10M 2207/046* (2013.01); *C10M 2207/2805* (2013.01)

USPC **508/494**; 508/579; 508/501; 508/496

(57) **ABSTRACT**

The present invention provides a lubricating oil composition having an extremely high viscosity index and a low coefficient of traction as a low coefficient of fluid friction in an elastohydrodynamic lubrication which is excellent in saving of energy and reduction in fuel consumption. The lubricating oil composition according to the present invention includes the following components (A) and (B): (A) a low-viscosity synthetic oil comprising a compound containing ether bond (s) in a molecule thereof and having a kinematic viscosity of less than 10 mm^2/s as measured at 40° C., in which a ratio of the number of oxygen atoms to the number of carbon atoms as constituents of the compound (O/C ratio) and the kinematic viscosity (mm^2/s) of the compound as measured at 40° C. satisfy the following formula (1); Kinematic Viscosity at 40° C.≤12−[(O/C ratio)×30] (1); and (B) a high-viscosity synthetic oil as a hydrocarbon-based synthetic oil having a kinematic viscosity of 40 mm^2/s or more as measured at 100° C. which includes at least one compound selected from the group consisting of an α-olefin oligomer, a hydrogenated α-olefin oligomer and an ethylene-propylene co-oligomer.

LUBRICATION OIL COMPOSITION

TECHNICAL FIELD

[0001] The present invention relates to a lubricating oil composition, and more particularly, to a lubricating oil composition having a high viscosity index and a low coefficient of fluid friction in an elastohydrodynamic lubrication which is excellent in saving of energy and reduction in fuel consumption.

BACKGROUND ART

[0002] Lubricating oils have been inherently used for the purpose of reducing friction at sliding portions by forming an oil film on the sliding portions. Therefore, in order to form a strong oil film, it is advantageous that the lubricating oils have a high viscosity. However, the lubricating oils having a high viscosity require a considerable amount of power upon stirring or supply thereof and therefore suffer from a large energy loss, thereby failing to achieve saving of energy and improvement in fuel consumption. In consequence, in recent years, reduction in viscosity of the lubricating oils has proceeded to prevent occurrence of a power loss.

[0003] However, if the viscosity of the lubricating oils is excessively reduced, it becomes difficult to form an oil film on sliding portions when exposed to a high temperature. As a result, there tend to occur increase in friction at the sliding portions and abnormal abrasion thereof.

[0004] For this reason, it has been required to reduce a viscosity of the lubricating oils in a normal temperature range while maintaining a high viscosity thereof under high temperature conditions. This means that the change in viscosity of the lubricating oils depending upon a temperature change thereof is extremely reduced, i.e., lubricating oils having an extremely high viscosity index (high VI) are required.

[0005] On the other hand, in many mechanical devices, there are used mechanical elements such as rolling bearings for supporting a rotating motion of members and gears for transmitting a power. Lubricating portions at the rolling bearings and gears are kept in an elastohydrodynamic lubrication, and the coefficient of friction at such portions is called a coefficient of traction. Therefore, in order to reduce a friction loss of the mechanical devices kept under such lubrication conditions, the lubricating oils used therefor have been required to have a traction reducing characteristic (i.e., reduce a coefficient of traction thereof).

[0006] However, it is not easy to reduce a coefficient of traction of the lubricating oils. In particular, it is not easy to reduce a coefficient of traction of the lubricating oils while enhancing a viscosity index thereof to an extreme extent.

[0007] As the method of solving these conventional problems, i.e., the method of reducing a coefficient of traction of the lubricating oils while enhancing a viscosity index thereof, there is known, for example, the method described in Patent Document 1.

[0008] Patent Document 1 discloses the method of reducing a coefficient of traction (i.e., tractive coefficient) of a lubricating oil composition containing a base stock having a viscosity larger than 3 cSt as measured at 100° C. by adding a traction reducer to the composition. As the traction reducer, there is described a monobasic acid ester or the like (refer to claims 1 and 4 of Patent Document 1). In addition, there is also described a lubricating oil composition having an increased viscosity index and a reduced coefficient of traction.

[0009] However, the effect of reducing a coefficient of traction of the lubricating oil composition as described in Patent Document 1 is not necessarily sufficient. Therefore, it has been required that the lubricating oil composition is further enhanced in the effect of reducing a coefficient of traction.

CITATION LIST

Patent Literature

[0010] Patent Document 1: JP 2008-530268A

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0011] An object of the present invention is to provide a lubricating oil composition having an extremely high viscosity index and a low coefficient of traction as a coefficient of fluid friction in an elastohydrodynamic lubrication which is excellent in saving of energy and reduction in fuel consumption.

Means for Solving the Problems

[0012] As a result of intense and extensive researches for achieving the above object, the present inventors have found that when compounding a specific low-viscosity synthetic oil containing ether bond(s) with a specific high-viscosity synthetic oil, the above object can be effectively achieved. The present invention has been accomplished on the basis of the above finding.

[0013] Thus, the present invention relates to the following aspects.

[0014] 1. A lubricating oil composition including the following components (A) and (B):

[0015] (A) a low-viscosity synthetic oil including a compound containing ether bond(s) in a molecule thereof and having a kinematic viscosity of less than 10 mm^2/s as measured at 40° C., in which a ratio of the number of oxygen atoms to the number of carbon atoms as constituents of the compound (O/C ratio) and the kinematic viscosity (mm^2/s) of the compound as measured at 40° C. satisfy the following formula (1):

$$\text{Kinematic Viscosity at } 40° \text{ C.} \leq 12-[(\text{O/C ratio})\times 30] \qquad (1);$$

and

[0016] (B) a high-viscosity synthetic oil as a hydrocarbon-based synthetic oil having a kinematic viscosity of 40 mm^2/s or more as measured at 100° C. which includes at least one compound selected from the group consisting of an α-olefin oligomer, a hydrogenated α-olefin oligomer and an ethylene-propylene co-oligomer.

[0017] 2. The lubricating oil composition as described in the above aspect 1, wherein the component (A) is at least one compound selected from the group consisting of the following compounds (a-1) to (a-3):

[0018] (a-1) a dialkyl ether of di- (or tri-) ethylene glycol (wherein two alkyl groups in the dialkyl ether may be the same or different from each other);

[0019] (a-2) di- (or tri-) ethylene glycol containing an alkyl ether at one terminal end thereof and an alkyl ester at the other terminal end thereof; and

[0020] (a-3) an alkoxyalkyl ester of a saturated or unsaturated fatty acid.

[0021] 3. The lubricating oil composition as described in the above aspect 1 or 2, wherein the component (B) is the α-olefin oligomer and/or hydrogenated α-olefin oligomer which have a kinematic viscosity of from 100 to 150 mm^2/s as measured at 100° C.

[0022] 4. The lubricating oil composition as described in any one of the above aspects 1 to 3, wherein the component (B) is the α-olefin oligomer and/or hydrogenated α-olefin oligomer which are produced by using a metallocene catalyst.

[0023] 5. The lubricating oil composition as described in any one of the above aspects 1 to 4, further including as a component (C), at least one lubricating oil additive selected from the group consisting of an antioxidant, an extreme pressure agent or an anti-wear agent, a dispersant and a metal-based detergent.

Effect of the Invention

[0024] In accordance with the present invention, it is possible to provide a lubricating oil composition having an extremely high viscosity index and a low coefficient of traction as a coefficient of fluid friction in an elastohydrodynamic lubrication which is excellent in saving of energy and reduction in fuel consumption. Therefore, it is also possible to provide a lubricating oil composition capable of reducing a power loss in mechanical devices including rolling bearings or gears which is excellent in saving of energy and reduction in fuel consumption.

Preferred Embodiments for Carrying Out the Invention

[0025] The lubricating oil composition according to present invention includes (A) a low-viscosity synthetic oil and (B) a high-viscosity synthetic oil.

[Low-Viscosity Synthetic Oil (Component A)]

[0026] The low-viscosity synthetic oil used as the component A in the present invention is required to be in the form of a compound containing ether bond(s) in a molecule thereof. The compound may contain at least one ether bond in a molecule thereof, and may also contain two or more ether bonds in a molecule thereof. The number of ether bonds contained in a molecule of the compound is preferably from 1 to 6, more preferably from 1 to 4 and still more preferably from 3 to 4.

[0027] The compound containing ether bond(s) in a molecule thereof as used in the present invention is not particularly limited as long as it contains the ether bond, and may also contain the other bond(s) such as, for example, ester bond(s).

[0028] It is required that the low-viscosity synthetic oil as the component A is in the form of a compound having a kinematic viscosity of less than 10 mm^2/s as measured at 40° C. The reason therefor is as follows. That is, since the component A is used in combination with the high-viscosity synthetic oil (as the component B) in the lubricating oil composition, it is required to reduce a kinematic viscosity of the composition and achieve saving of energy and reduction in fuel consumption. For this reason, the kinematic viscosity of the component A as measured at 40° C. is preferably not more than 9 mm^2/s, more preferably not more than 8 mm^2/s and still more preferably not more than 5 mm^2/s.

[0029] Meanwhile, the lower limit of the kinematic viscosity of the component A as measured at 40° C. is not particularly limited, and is preferably not less than 1 mm^2/s and more preferably not less than 1.5 mm^2/s from the viewpoint of preventing occurrence of evaporation loss of the lubricating oil composition.

[0030] The compound containing ether bond(s) in a molecule thereof as the component A is further required to be a low-viscosity synthetic oil in which a ratio of the number of oxygen atoms to the number of carbon atoms as constituents of the compound (O/C ratio) and the kinematic viscosity (mm^2/s) of the compound as measured at 40° C. satisfy the following formula (1):

$$\text{Kinematic Viscosity at } 40^\circ \text{ C.} \leq 12-[(\text{O/C ratio})\times 30] \quad (1).$$

[0031] The compound containing ether bond(s) in a molecule thereof which has the O/C ratio controlled so as to satisfy the above formula (1) has a good solubility and can exhibit a low viscosity and a well-controlled viscosity index. Meanwhile, in order to further enhance the above effects, the upper limit of the right-side value of the above formula (1) is preferably adjusted to 8.5.

[0032] The component A used in the present invention may be any compound as long as it satisfies the above requirement, and is preferably is at least one compound selected from the group consisting of the following compounds (a-1) to (a-3) from the viewpoint of a good availability:

[0033] (a-1) a dialkyl ether of di- (or tri-) ethylene glycol (wherein two alkyl groups in the dialkyl ether may be the same or different from each other);

[0034] (a-2) di- (or tri-)ethylene glycol containing an alkyl ether at one terminal end thereof and an alkyl ester at the other terminal end thereof; and

[0035] (a-3) an alkoxyalkyl ester of a saturated or unsaturated fatty acid.

[0036] The number of carbon atoms in the alkyl ether, the alkyl ester, the alkoxyalkyl ester and the fatty acid, concerning the above compounds (a-1) to (a-3) may be determined such that the condition of the kinematic viscosity of the respective compounds as measured at 40° C. and the above formula (1) are satisfied.

[0037] Examples of the alkyl ether include ethyl ether, propyl ether, butyl ether, hexyl ether and hexyl butyl ether. The ether group of these alkyl ethers may be in the form of a monoether, a diether, a triether or the like. Among these alkyl ethers, preferred is dibutyl ether. Examples of the alkyl ester include a decanoic acid alkyl ester, an octanoic acid alkyl ester and a nonanoic acid alkyl ester. Among these alkyl esters, preferred is an octanoic acid alkyl ester. Examples of the alkoxyalkyl ester of a saturated or unsaturated fatty acid include a palmitoleic acid butoxyethyl ester, an oleic acid butoxyethyl ester and an elaidic acid butoxyethyl ester. Among these the alkoxyalkyl esters of a saturated or unsaturated fatty acid, preferred is an oleic acid butoxyethyl ester.

[0038] These compounds containing ether bond(s) in a molecule thereof as the component A may be used alone or in the form of a mixture of any two or more thereof. The content of the component A is preferably from 20 to 90% by mass, more preferably from 30 to 80% by mass and still more preferably from 50 to 80% by mass on the basis of a total amount of the component A and the below-mentioned component B. When the content of the component A is 20% by mass or more, it is possible to attain the effect of reducing a coefficient of traction of the lubricating oil composition, and at the same time, reduce a viscosity of the composition. On the other hand, When the content of the component A is 90% by mass or less, it is possible to obtain a lubricating oil composition having a good solubility and a high stability.

[0039] Also, the lower limit of the kinematic viscosity of the low-viscosity synthetic oil (component A) as measured at 100° C. is preferably 0.5 mm^2/s or more, and more preferably 0.7 mm^2/s or more, whereas the upper limit of the kinematic viscosity of the low-viscosity synthetic oil (component A) as measured at 100° C. is preferably 3.0 mm^2/s or less, more preferably 2.0 mm^2/s or less and still more preferably 1.5 mm^2/s or less.

[0040] When the kinematic viscosity of the component A as measured at 100° C. is controlled to the above-specified range, it is possible to readily achieve both a high viscosity index and a low viscosity of the lubricating oil composition.

[High-Viscosity Synthetic Oil (Component B)]

[0041] In the present invention, as the component B, there is used a hydrocarbon-based synthetic oil having a kinematic viscosity of 40 mm^2/s or more as measured at 100° C.

[0042] When the kinematic viscosity of the component B as measured at 100° C. is less than 40 mm^2/s, it is not necessarily possible to obtain a lubricating oil composition having a sufficiently high viscosity index. Therefore, the kinematic viscosity of the component B as measured at 100° C. is preferably 50 mm^2/s or more, more preferably 80 mm^2/s or more and still more preferably 100 mm^2/s or more.

[0043] The upper limit of the kinematic viscosity of the component B as measured at 100° C. is not particularly limited, but is preferably 150 mm^2/s or less and more preferably 130 mm^2/s or less in view of preventing deterioration in shear stability of the lubricating oil composition.

[0044] From these viewpoints, the kinematic viscosity of the component B as measured at 100° C. is preferably from 100 to 150 mm^2/s and more preferably from 100 to 130 mm^2/s.

[0045] In the present invention, as the above hydrocarbon-based high-viscosity synthetic oil (component B), there may be used at least one compound selected from the group consisting of an α-olefin oligomer, a hydrogenated α-olefin oligomer and an ethylene-propylene co-oligomer. Among these compounds, from the viewpoint of suppressing increase in viscosity of the composition at a low temperature, preferred are the α-olefin oligomer and/or the hydrogenated α-olefin oligomer.

[0046] The raw material of the α-olefin oligomer or the hydrogenated α-olefin oligomer may have any α-olefin having a straight chain structure or a branched chain structure. Specifically, α-olefins having 8 to 12 carbon atoms which are selected from the group consisting of 1-octene, 1-nonene, 1 decene, 1-undecene and 1-dodecene may be used singly or in combination of any two or more thereof.

[0047] Of these compounds, there may be suitably used the α-olefin oligomer and/or the hydrogenated α-olefin oligomer which are produced by using 1-decene as the raw material.

[0048] The polymerization for producing the above α-olefins may be carried out by using various polymerization (oligomerization) catalysts. Examples of the polymerization catalysts include metallocene catalysts and so-called non-metallocene catalysts such as boron trifluoride (BF) and Ziegler catalysts.

[0049] Of these oligomers, the α-olefin oligomers produced using the metallocene catalysts and the hydrogenated α-olefin oligomers produced by further hydrogenating the α-olefin oligomers are preferred from the viewpoint of a high viscosity index thereof.

[0050] As the metallocene catalysts, a complex having a conjugated carbon 5-membered ring containing an element belonging to Group 4 of the Periodic Table, i.e., a metallocene complex, may be used in combination with an oxygen-containing organoaluminum compound.

[0051] Examples of the element belonging to Group 4 of the Periodic Table contained in the metallocene complex include titanium, zirconium and hafnium. Among these elements, preferred is zirconium. The complex having a conjugated carbon 5-membered ring may be used in the form of a complex having a substituted or unsubstituted cyclopentadienyl ligand. Suitable examples of the metallocene complex include bis(n-octadecyl cyclopentadienyl) zirconium dichloride, bis(trimethylsilyl cyclopentadienyl) zirconium dichloride, bis(tetrahydroindenyl) zirconium dichloride, bis[(t-butyldimethylsilyl) cyclopentadienyl]zirconium dichloride, bis (di-t-butyl cyclopentadienyl) zirconium dichloride, (ethylidene-bisindenyl) zirconium dichloride, biscyclopentadienyl zirconium dichloride, ethylidnebis(tetrahydroindenyl) zirconium dichloride and bis[3,3(2-methyl-benzindenyl)] dimethylsilane-diyl zirconium dichloride. These metallocene complexes may be used alone or in combination of any two or more thereof.

[0052] On the other hand, examples of the oxygen-containing organoaluminum compound include methyl alumoxane, ethyl alumoxane and isobutyl alumoxane. These oxygen-containing organoaluminum compounds may be used alone or in combination of any two or more thereof.

[0053] The ethylene-propylene co-oligomer used as the component B is not particularly limited, and may be used in the form of an ethylene-propylene copolymer having an ethylene content of usually from 10 to 90 mol % and preferably from 20 to 80 mol %. Such a co-oligomer can exhibit a high viscosity index and a good shear stability.

[0054] The content of the component B in the lubricating oil composition is preferably from 80 to 10% by mass, more preferably 70 to 20% by mass and still more preferably from 50 to 20% by mass on the basis of a total amount of the components A and B. When the content of the component B in the lubricating oil composition is 10% by mass or more, it is possible to obtain a lubricating oil having a high viscosity index. When the content of the component B in the lubricating oil composition is 80% by mass or less, it is possible to obtain a stable composition having a good solubility.

[0055] The total content of the components A and B in the lubricating oil composition is preferably 70% by mass or more, more preferably 80% by mass or more, and still more preferably 90% by mass or more.

[Lubricating Oil Additive (Component C)]

[0056] The lubricating oil composition containing the components A and B according to the present invention may be further compounded with a lubricating oil additive as a component C.

[0057] As the lubricating oil additive as the component C, there may be mentioned (c-1) an antioxidant, (c-2) an extreme pressure agent or an anti-wear agent, (c-3) a dispersant and (c-4) a metal-based detergent, etc. One or more lubricating oil additives selected from these materials are preferably compounded in the lubricating oil composition.

[0058] Examples of the antioxidant as the component (c-1) include an amine-based antioxidant, a phenol-based antioxidant and a sulfur-based antioxidant.

[0059] Specific examples of the amine-based antioxidant include dialkyl (number of carbon atoms in the alkyl group: from 1 to 20) diphenyl amines such as 4,4'-dibutyl diphenyl amine, 4,4'-dioctyl diphenyl amine and 4,4'-dinonyl diphenyl amine; and naphthyl amines such as phenyl-α-naphthyl amine, octyl phenyl-α-naphthyl amine and nonyl phenyl-α-naphthyl amine.

[0060] Specific examples of the phenol-based antioxidant include monophenol-based antioxidants such as 2,6-di-tert-butyl-4-methyl phenol and 2,6-di-tert-butyl-4-ethyl phenol; and diphenol-based antioxidants such as 4,4'-methylenebis (2,6-di-tert-butyl phenol) and 2,2'-methylenebis(4-ethyl-6-tert-butyl phenol).

[0061] Specific examples of the sulfur-based antioxidant include phenothiazine, pentaerythritol-tetrakis-(3-lauryl thiopropionate), bis(3,5-tert-butyl-4-hydroxybenzyl) sulfide, thiodiethylenebis(3-(3,5-di-tert-butyl-4-hydroxyphenyl)) propionate and 2,6-di-tert-butyl-4-(4,6-bis(octylthio)-1,3,5-triazine-2-methylamino) phenol.

[0062] These antioxidants may be used alone or in combination of any two or ore thereof. The amount of the antioxidant compounded in the lubricating oil composition is usually from 0.01 to 10% by mass and preferably from 0.03 to 5% by mass on the basis of a whole amount of the lubricating oil composition.

[0063] Examples of the extreme pressure agent or anti-wear agent as the component (c-2) include a sulfur-based extreme pressure agent, a phosphorus-based anti-wear agent, an S—P-based extreme pressure agent, zinc hydrocarbyl dithiophosphate and a thiazole-based extreme pressure agent.

[0064] Specific examples of the sulfur-based extreme pressure agent include sulfurized oils and fats, sulfurized fatty acids, sulfurized esters, sulfurized olefins, dihydrocarbyl polysulfides, thiadiazole compounds, alkyl thiocarbamoyl compounds, thiocarbamate compounds, thioterpene compounds and dialkyl thiodipropionate compounds.

[0065] Specific examples of the phosphorus-based anti-wear agent include phosphoric acid ester compounds such as phosphoric acid esters, acidic phosphoric acid esters, phosphorous acid esters and acidic phosphorous acid esters, and amine salts of these phosphoric acid ester compounds.

[0066] The S—P-based extreme pressure agent may be in the form of either a compound containing sulfur and phosphorus in a molecule thereof such as triphenyl thiophosphate and lauryl trithiophosphate, or a mixture of the sulfur-based extreme pressure agent and the phosphorus-based extreme pressure agent. When the S—P-based extreme pressure agent is used in the form of a mixture of the sulfur-based extreme pressure agent and the phosphorus-based extreme pressure agent, the respective extreme pressure agents may be selected from the sulfur-based extreme pressure agents and the phosphorus-based extreme pressure agents as exemplified above.

[0067] In addition, the hydrocarbyl group of the zinc dihydrocarbyl dithiophosphate (ZnDTP) may be any of a linear or branched alkyl group having 1 to 24 carbon atoms, a linear or branched alkenyl group having 3 to 24 carbon atoms, a cycloalkyl group or linear or branched alkyl cycloalkyl group having 5 to 13 carbon atoms, an aryl group or linear or branched alkyl aryl group having 6 to 18 carbon atoms, and an arylalkyl group having 7 to 19 carbon atoms, etc. Also, the alkyl group or the alkenyl group as the hydrocarbyl group may be in the form of either a primary group, a secondary group or a tertiary group.

[0068] Specific examples of the thiadiazole compounds include 2,5-bis(n-hexyldithio)-1,3,4-thiadiazole, 2,5-bis(n-octyldithio)-1,3,4-thiadiazole, 2,5-bis(n-nonyldithio)-1,3,4-thiadiazole, 2,5-bis(1,1,3,3-tetramethylbutyldithio)-1,3,4-thiadiazole, 3,5-bis(n-hexyldithio)-1,2,4-thiadiazole, 3,6-bis (n-octyldithio)-1,2,4-thiadiazole, 3,5-bis(n-nonyldithio)-1,2,4-thiadiazole, 3,5-bis(1,1,3,3-tetramethylbutyldithio)-1,2,4-thiadiazole, 4,5-bis(n-octyldithio)-1,2,3-thiadiazole, 4,5-bis (n-nonyldithio)-1,2,3-thiadiazole and 4,5-bis(1,1,3,3-tetramethylbutyldithio)-1,2,3-thiadiazole.

[0069] These extreme pressure agents or anti-wear agents may be used alone or in combination of any two or more thereof. The amount of the extreme pressure agent or anti-wear agent compounded in the lubricating oil composition is usually in the range of from 0.01 to 10% by mass and preferably from 0.05 to 5% by mass on the basis of a whole amount of the lubricating oil composition.

[0070] Examples of the dispersant as the component (c-3) include an imide-based dispersant, an amide-based dispersant and an ester-based dispersant.

[0071] Specific examples of the dispersant include an alkenyl group-substituted alkenyl succinic acid imide having an average molecular weight of from 1000 to 3500 or a boronated product thereof, benzyl amine, alkyl polyamines and alkenyl succinic acid esters.

[0072] These dispersants may be used alone or in combination of any two or more thereof. The amount of the dispersant compounded in the lubricating oil composition is usually in the range of from 0.05 to 10% by mass and preferably from 0.1 to 5% by mass on the basis of a whole amount of the lubricating oil composition.

[0073] Examples of the metal-based detergent as the component (c-4) include sulfonates of alkali earth metals such as Ca, Mg and Ba, phenates of alkali earth metals, salicylates of alkali earth metals and phosphonates of alkali earth metals. These metal-based detergents may be either neutral, basic or perbasic.

[0074] These metal-based detergents may be used alone or in combination of any two or more thereof. The amount of the metal-based detergent compounded in the lubricating oil composition is usually in the range of from 0.05 to 30% by mass and preferably from 0.1 to 10% by mass on the basis of a whole amount of the lubricating oil composition.

[0075] As the lubricating oil additives, in addition to the above components, there may be appropriately compounded the other additives such as an oiliness agent, a rust-preventive agent, a metal deactivator, an anti-corrosion agent, a pour point depressant and a defoamer.

[0076] The total amount of the lubricating oil additives compounded in the lubricating oil composition of the present invention is usually from 1 to 20 parts by mass and preferably from 3 to 15 parts by mass on the basis of 100 parts by mass of a sum of the components A and B.

[Other Components]

[0077] The lubricating oil composition of the present invention may be further compounded with a lubricant base oil in addition to the above components unless the object of the present invention is adversely affected by addition of the lubricant base oil.

[0078] Examples of the lubricant base oil include mineral oils having a kinematic viscosity of 10 mm^2/s or less as measured at 100° C., and synthetic oils such as α-olefin oligomers, polybutene and polyol esters. The base oil is preferably compounded in an amount of 30% by mass or less on the basis of the lubricating oil composition.

[Lubricating Oil Composition]

[0079] As described above, the lubricating oil composition of the present invention contains the components A and B, and further may contain the component C, if required. The viscosity index of the lubricating oil composition of the present invention is preferably 220 or more, more preferably 240 or more, and still more preferably 260 or more. When the viscosity index of the lubricating oil composition is 220 or more, the resulting composition can readily form an oil film on sliding portions at a high temperature while achieving saving of energy and reduction in fuel consumption.

[0080] The coefficient of traction of the lubricating oil composition of the present invention is preferably 0.025 or less and more preferably 0.020 or less. When the coefficient of traction of the lubricating oil composition is 0.025 or less, the resulting composition can exhibit a sufficient effect of reducing a coefficient of fluid friction in an elastohydrodynamic lubrication.

[0081] Meanwhile, the coefficient of traction is the value as measured by the below-mentioned evaluation method.

[0082] The kinematic viscosity of the lubricating oil composition of the present invention is not particularly limited and may be appropriately determined according to the aimed applications or conditions upon use of the lubricating oil composition.

[0083] For example, in the case where the lubricating oil composition is used as a transmission fluid for vehicles, the kinematic viscosity of the lubricating oil composition as measured at 40° C. is preferably 25 mm^2/g or less, and the kinematic viscosity of the lubricating oil composition as measured at 100° C. is preferably 6 mm^2/g or more.

[0084] The lubricating oil composition of the present invention is capable of reducing a power loss in mechanical devices including rolling bearings or gears as mechanical elements, can provide a lubricating oil that is excellent in saving of energy and reduction in fuel consumption, and can be suitably used as industrial bearing oils, industrial gear oils, gear oils for vehicles, transmission fluids for vehicles, etc.

EXAMPLES

[0085] The present invention will be described in more detail by referring to the following examples, etc. However, it should be noted that these examples are only illustrative and not intended to limit the invention thereto.

Examples 1 to 12 and Comparative Examples 1 to 11

[0086] The lubricating oil compositions having the formulations shown in Table 2 were prepared using the base materials shown in Table 1, and the viscosity index, kinematic viscosity, solubility and coefficient of traction of the obtained lubricating oil compositions were measured. The lubricating oil compositions were prepared by the method in which the respective base materials used for preparing the compositions were stirred and mixed at 60° C. for 30 min.

[0087] Meanwhile, the additives used in the respective Examples and Comparative Examples shown in Table 2 were used in the form of a package of the compounds shown in the column "Content" for "Add (Additives)" in Table 1, and all were constituted of the same package.

[0088] In addition, the symbols used for indicating the respective base materials as shown in Table 1 and also employed in Table 2 mean the following groups of compounds.

[0089] ET: Compounds containing ether bond(s);

[0090] ETS: Compounds containing ether bond(s) and ester bond(s);

[0091] ES: Compounds containing ester bond(s);

[0092] PAO: α-Olefin oligomers;

[0093] HV-PAO: High-viscosity α-olefin oligomers;

[0094] EPO: Ethylene-propylene co-oligomers;

[0095] PB: Polybutene.

[0096] The properties and performance of the lubricating oil compositions were measured by the following methods.

<Method for Measuring Properties of Lubricating Oil Composition>

(1) Kinematic Viscosity

[0097] Measured according to JIS K2283.

(2) Viscosity Index

[0098] Measured according to JIS K2283.

<Method for Evaluating Performance of Lubricating Oil Composition>

(3) Solubility of Lubricating Oil Composition

[0099] The lubricating oil composition prepared by the above method was allowed to stand at room temperature for 8 h, and then an appearance of the lubricating oil composition was observed by naked eyes to examine whether or not any insoluble components were precipitated.

[0100] The case where the lubricating oil composition was free from precipitation of insoluble components and exhibited a good solubility was expressed by "OK", whereas the case where the lubricating oil composition suffered from precipitation of insoluble components and exhibited a poor solubility was expressed by "NG".

(4) Coefficient of Traction

[0101] The coefficient of traction of the lubricating oil composition was measured using the following testing machine under the following conditions.

Testing Machine:

[0102] "Mini Traction Machine" available from PCS Instruments Limited.

Measuring Conditions:

[0103] Ball: 19.05 mm in diameter; made of AISI 52100 bearing steel,

[0104] Disc: 50 mm in diameter; made of AISI 52100 bearing steel,

[0105] Rolling speed: 4.0 m/s,

[0106] Load: 45 N,

[0107] Oil temperature: 40° C., and

[0108] Slip ratio: 10%.

TABLE 1

Symbol for raw materials	Content	Number of C	Number of O	O/C atomic ratio	Kinematic viscosity at 40° C.	Kinematic viscosity at 100° C.	Viscosity index	Right-side value of formula (1)	Formula (1) can be satisfied or unsatisfied
Low-viscosity base material									
ET1	*1	16	4	0.25	3.25	1.35	—	4.5	○
ET2	*2	14	4	0.286	2.67	1.16	—	3.4	○
ET3	*3	14	3	0.214	2.39	1.07	—	5.6	○
ET4	*4	13	3	0.231	1.84	0.85	—	5.1	○
ETS1	*5	24	3	0.125	7.51	2.54	197	8.3	○
ETS2	*6	18	4	0.222	4.85	1.77	—	5.3	○
ETS3	*7	16	4	0.25	4.11	1.55	—	4.5	○
ETS4	*8	16	4	0.25	3.87	1.5	—	4.5	○
ETS5	*9	22	6	0.273	8.92	2.72	158	3.8	x
ETS6	*10	18	5	0.278	5.17	1.86	—	3.7	x
ETS7	*11	24	5	0.208	10	2.94	158	5.8	x
ET4 + ETS1	*12	—	—	0.176	4.79	1.82	—	6.7	○
ES1	*13	—	—	—	5.78	2.07	188	—	—
ES2	*14	—	—	—	3.83	1.51	—	—	—
ES3	*15	—	—	—	3.36	1.36	—	—	—
ES4	*16	—	—	—	11.5	3.2	152	—	—
ES5	*17	—	—	—	3.13	1.3	—	—	—
PAO	*18	—	—	—	5.29	1.7	—	—	—
Mineral oil	*19	—	—	—	7.51	2.25	108	—	—
High-viscosity base material									
HV-PAO1	*20	—	—	—	1370	129	199	—	—
HV-PAO2	*21	—	—	—	1260	99.6	167	—	—
EPO	*22	—	—	—	1300	100	165	—	—
HV-PAO3	*23	—	—	—	400	47.9	181	—	—
PB	*24	—	—	—	—	224	—	—	—
Additives									
Add	*25	—	—	—	—	—	—	—	—

Note
*1: Triethylene glycol hexyl butyl diether;
*2: Triethylene glycol dibutyl ether;
*3: Diethylene glycol hexyl butyl ether;
*4: Diethylene glycol dibutyl ether;
*5: Oleic acid butoxyethyl ester;
*6: Diethylene glycol monobutyl ether n-decanoic acid ester;
*7: Diethylene glycol monoethyl ether n-decanoic acid ester;
*8: Diethylene glycol monobutyl ether n-octanoic acid ester;
*9: Triethylene glycol n-octanoic acid diester;
*10: Triethylene glycol monobutyl ether n-octanoic acid ester;
*11: Diethylene glycol n-decanoic diester;
*12: Mixed oil of ET4 (28 wt %) + ETS1 (72 wt %);
*13: Dibutyl sebacate;
*14: Diethyl sebacate;
*15: Diethyl azelate;
*16: Di-2-ethylhexyl sebacate;
*17: Isononyl alcohol heptanoic acid ester;
*18: 1-Decene oligomer ("Durasyn 162" available from INEOS);
*19: Hydrocracked mineral oil "Ultra S-2" available from S-Oil Corp.;
*20: "IDEMITSU LINEARLENE PAO-V-120" available from Idemitsu Kosan Co., Ltd.;
*22: "Lucant HC100" available from Mitsui Chemicals, Inc.;
*23: "IDEMITSU LINEARLENE PAO-V-50" available from Idemitsu Kosan Co., Ltd.;
*24: "Nisseki Polybutene HV-100" available from JX Nippon Oil & Energy Corp.;
*25: S-P extreme pressure agent, ZnDTP, Mg sulfonate, imide-based dispersant and defoamer.

TABLE 2-1

	Examples											
	1	2	3	4	5	6	7	8	9	10	11	12
Formulations of base materials (mass %)												
Low-viscosity base material												
ET1	57.0	—	—	—	—	—	—	—	—	—	—	—
ET2	—	55.0	—	—	—	—	—	—	—	—	—	—
ET3	—	—	53.5	—	—	—	—	—	—	—	—	—
ET4	—	—	—	50.5	—	—	—	—	—	—	—	—
ETS1	—	—	—	—	69.5	—	—	—	—	—	—	58.0
ETS2	—	—	—	—	—	62.0	—	—	—	—	—	—
ETS3	—	—	—	—	—	—	60.0	—	—	—	—	—
ETS4	—	—	—	—	—	—	—	59.0	—	—	—	—
ETS5	—	—	—	—	—	—	—	—	—	—	—	—
ETS6	—	—	—	—	—	—	—	—	—	—	—	—
ETS7	—	—	—	—	—	—	—	—	—	—	—	—
ET4 + ETS1	—	—	—	—	—	—	—	—	62.0	62.0	67.0	
ES1, ES2, ES3, ES4, ES5	—	—	—	—	—	—	—	—	—	—	—	—
PAO	—	—	—	—	—	—	—	—	—	—	—	—
Mineral oil	—	—	—	—	—	—	—	—	—	—	—	—
High-viscosity base material												
HV-PAO1	35.0	37.0	38.5	41.5	22.5	30.0	32.0	33.0	30.0	—	—	—
HV-PAO2	—	—	—	—	—	—	—	—	—	30.0	—	—
EPO	—	—	—	—	—	—	—	—	—	—	25.0	—
HV-PAO3	—	—	—	—	—	—	—	—	—	—	—	34.0
PB	—	—	—	—	—	—	—	—	—	—	—	—
Additives												
Add	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Properties and performance of composition												
Solubility	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Kinematic viscosity at 40° C. [mm^2/s]	21.3	20.9	20.3	19.9	22.4	22.1	22.5	22.3	21.4	223	22.7	24.2
Kinematic viscosity at 100° C. [mm^2/s]	6.13	6.03	6.15	6.16	6.05	6.07	6.09	6.16	6.1	6	6.15	6.16
Viscosity index [—]	267	267	286	295	242	248	242	251	262	240	244	222
Coefficient of traction [—]	0.016	0.014	0.016	0.015	0.019	0.02	0.019	0.019	0.018	0.018	0.018	0.024

TABLE 2-2

	Comparative Examples										
	1	2	3	4	5	6	7	8	9	10	11
Formulations of base materials (mass %)											
Low-viscosity base material											
ET1, ET2, ET3, ET4	—	—	—	—	—	—	—	—	—	—	—
ETS1	—	—	—	—	—	—	—	—	—	—	—
ETS2	—	—	—	—	—	—	—	—	—	—	—
ETS3	—	—	—	—	—	—	—	—	—	—	—
ETS4	—	—	—	—	—	—	—	—	—	—	—
ETS5	67.0	—	—	—	—	—	—	—	—	—	—
ETS6	—	62.0	—	—	—	—	—	—	—	—	—
ETS7	—	—	72.0	—	—	—	—	—	—	—	—
ET4 + ETS1	—	—	—	—	—	—	—	—	—	—	55.0
ES1	—	—	—	67.0	—	—	—	—	—	—	—
ES2	—	—	—	—	60.0	—	—	—	—	—	—
ES3	—	—	—	—	—	58.0	—	—	—	—	—
ES4	—	—	—	—	—	—	75.0	—	—	—	—
ES5	—	—	—	—	—	—	—	58.4	—		—
PAO	—	—	—	—	—	—	—	—	62.5	—	—
Mineral oil	—	—	—	—	—	—	—	—	—	68.0	—
High-viscosity base material											
HV-PAO1	25.0	30.0	20.0	25.0	32.0	34.0	17.0	33.6	29.5	24.0	—
HV-PAO2	—	—	—	—	—	—	—	—	—	—	—
EPO	—	—	—	—	—	—	—	—	—	—	—

TABLE 2-2-continued

	Comparative Examples										
	1	2	3	4	5	6	7	8	9	10	11
HV-PAO3	—	—	—	—	—	—	—	—	—	—	—
PB	—	—	—	—	—	—	—	—	—	—	37.0
Additives											
Add	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Properties and performance of composition											
Solubility	NG	NG	OK	NG	NG	NG	OK	OK	OK	OK	OK
Kinematic viscosity at 40° C. [mm^2/s]	—	—	24.3	—	—	—	25.3	20.8	24.3	25.7	27.3
Kinematic viscosity at 100° C. [mm^2/s]	—	—	6.03	—	—	—	6.09	6.02	6.04	6.15	6.11
Viscosity index [—]	—	—	212	—	—	—	204	267	214	202	183
Coefficient of traction [—]	—	—	0.031	—	—	—	0.038	0.037	0.032	0.046	0.048

[0109] From Table 2, the followings are recognized.

[0110] The lubricating oil compositions containing the low-viscosity synthetic oils and the high-viscosity synthetic oils according to the present invention had an extremely high viscosity index of 220 or more and an extremely small coefficient of traction of 0.024 or less, exhibited a good solubility and therefore were in the form of a stable composition (Examples 1 to 12).

[0111] On the other hand, in Comparative Examples 1 to 3 in which the low-viscosity synthetic oils were compounds containing ether bond(s) which were incapable of satisfying the formula (1), in Comparative Examples 3 and 7 in which the low-viscosity synthetic oils had a kinematic viscosity of 10 mm^2/s or more (as measured at 40° C.), in Comparative Examples 4 to 10 in which the low-viscosity synthetic oils were not compounds containing ether bond(s), and in Comparative Example 11 in which the high-viscosity synthetic oil was not a compound as defined by the present invention, the resulting compositions all failed to achieve the aimed object of the present invention, i.e., suffered from defects such as production of an unstable composition and a large coefficient of traction.

INDUSTRIAL APPLICABILITY

[0112] According to the present invention, it is possible to provide a lubricating oil composition having not only an extremely high viscosity index but also a low coefficient of traction as a low coefficient of fluid friction in an elastohydrodynamic lubrication which is excellent in saving of energy and reduction in fuel consumption. Therefore, the lubricating oil composition of the present invention is excellent in saving of energy and reduction in fuel consumption since the composition is capable of reducing a power loss, in particular, in mechanical devices including rolling bearings or gears, and can be suitably used in the form of various lubricating oil compositions as industrial bearing oils, industrial gear oils, gear oils for vehicles, transmission fluids for vehicles, etc.

1. A lubricating oil composition, comprising:

(A) a low-viscosity synthetic oil comprising a compound comprising an ether bond in a molecule thereof and having a kinematic viscosity of less than 10 mm^2/s as measured at 40° C., in which a ratio of number of oxygen atoms to number of carbon atoms as constituents of the compound (O/C ratio) and the kinematic viscosity (mm^2/s) of the compound as measured at 40° C. satisfy formula (1):

$$\text{Kinematic Viscosity at 40° C.} \leq 12-[(\text{O/C ratio})\times 30] \quad (1);$$

and

(B) a high-viscosity synthetic oil as a hydrocarbon-based synthetic oil having a kinematic viscosity of 40 mm^2/s or more as measured at 100° C. which comprises at least one compound selected from the group consisting of an α-olefin oligomer, a hydrogenated α-olefin oligomer and an ethylene-propylene co-oligomer.

2. The lubricating oil composition according to claim **1**, wherein the component (A) is at least one compound selected from the group consisting of:

(a-1) a dialkyl ether of di- or tri-ethylene glycol, wherein two alkyl groups in the dialkyl ether may be the same or different from each other;

(a-2) di- or tri-ethylene glycol comprising an alkyl ether at one terminal end thereof and an alkyl ester at the other terminal end thereof; and

(a-3) an alkoxyalkyl ester of a saturated or unsaturated fatty acid.

3. The lubricating oil composition according to claim **1**, wherein the component (B) is the α-olefin oligomer, hydrogenated α-olefin oligomer, or both, which have a kinematic viscosity of from 100 to 150 mm^2/s as measured at 100° C.

4. The lubricating oil composition according to claim **1**, wherein the component (B) is the α-olefin oligomer, hydrogenated α-olefin oligomer, or both, which are produced with a metallocene catalyst.

5. The lubricating oil composition according to claim **1**, further comprising as a component (C), at least one lubricating oil additive selected from the group consisting of an antioxidant, an extreme pressure agent an anti-wear agent, a dispersant and a metal-based detergent.

* * * * *