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(54) LUBRICATING OIL COMPOSITION

(57) The present invention provides a lubricating oil composition having a low traction coefficient that can reduce the friction between parts such as gear teeth surfaces, exposed to elastohydrodynamic lubrication conditions to attain energy saving properties and high efficiency, suitable for use in manual, automatic and continuously variable transmissions of automobiles or industrial gear systems. The low traction coefficient lubricating oil composition comprises a lubricating base oil containing (A) a partial ester of a polyhydric alcohol and a carboxylic acid in an amount of 0.1 to 80 percent by mass on the basis of the total mass of the base oil and having a kinematic viscosity at 100°C of 1 to 15 mm^2/s, the composition having a kinematic viscosity at 100°C of 1 to 20 mm^2/s.

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Description

Technical Field

[0001] The present invention relates to a lubricating oil composition, more specifically to such a lubricating oil composition having a low traction coefficient, excellent energy saving properties, and high efficiency, which is suitable for use in manual, automatic or continuously variable transmissions of automobiles, or in industrial gear systems.

Background Art

[0002] Recently, energy saving in automobiles and construction or agricultural machinery, i.e., fuel saving has become an urgent need in order to deal with environmental issues such as reduction in carbon dioxide emissions, and units such as engines, transmissions, final reduction gears, compressors, or hydraulic power units have been strongly demanded to contribute to energy saving. Consequently, the lubricating oils used in these systems are required to be reduced in stir resistance and frictional resistance more than before.

[0003] Reducing the viscosity of a lubricating oil can be pointed out as an effective energy saving means for a transmission and a final reduction gear unit. For example, an automobile automatic transmission or continuously variable transmission has a torque converter, a wet clutch, a gear bearing mechanism, an oil pump and a hydraulic control system while a manual transmission or final reduction gear unit has a gear bearing mechanism. Reducing the viscosity of a lubricating oil to be used in such transmissions can reduce the stir and frictional resistances in the torque converter, wet clutch, gear bearing mechanism and oil pump and thus enhance the power transmission efficiency, resulting in an improvement in the fuel economy performance of an automobile.

[0004] However, reducing the viscosity of the lubricating oil used in these transmissions may cause the above-described units and mechanisms thereof to be significantly shortened in fatigue life and may generate seizure resulting in some malfunctions in the transmissions. In particular when a low viscosity lubricating oil is blended with a phosphorus-based extreme pressure additive to enhance the extreme pressure properties, the fatigue life will be extremely shortened. In general it is thus difficult to reduce the viscosity of the lubricating oil. Although a sulfur-based extreme pressure additive can improve the fatigue life, the oxidation stability of a lubricating oil is deteriorated and thus a large amount of an antioxidant must be blended.

[0005] As described above, reducing the viscosity has some limits. Alternatively or in addition to the reducing of the viscosity, energy saving or high energy efficiency can be achieved effectively by reducing friction on parts such as gear teeth surfaces exposed to elastohydrodynamic lubricating conditions. In general, the contact pressure applied to gear teeth surfaces may be 1 GPa or greater, which is known to be under elastohydrodynamic lubricating conditions. Under these conditions, the use of a lubricating oil having a low traction coefficient is known to reduce friction and thus contribute to energy saving.

Citation List

Patent Literatures

[0006] Patent Literature 1: Japanese Patent Application Laid-Open Publication No. 10-213552
Patent Literature 2: Japanese Patent Application Laid-Open Publication No. 9-68161

Summary of Invention

Technical Problem

[0007] The present invention was made in view of these circumstances and has an object to provide a lubricating oil composition having a low traction coefficient that can reduce the friction between parts such as gear teeth surfaces, exposed to elastohydrodynamic lubrication conditions to attain energy saving properties and high efficiency, suitable for use in manual, automatic and continuously variable transmissions of automobiles or industrial gear systems.

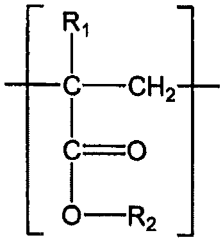
Solution to Problem

[0008] As the result of extensive study and research, the present invention was accomplished on the basis of the finding that the above problems could be solved using a lubricating oil composition comprising a base oil containing (A) a partial ester of a polyhydric alcohol and a carboxylic acid.

[0009] That is, the present invention relates to a lubricating oil composition having a low traction coefficient, comprising a lubricating base oil containing (A) a partial ester of a polyhydric alcohol and a carboxylic acid in an amount of 0.1 to 80 percent by mass on the basis of the total mass of the base oil and having a kinematic viscosity at 100°C of 1 to 15 mm^2/s, the composition having a kinematic viscosity at 100°C of 1 to 20 mm^2/s.

[0010] The present invention also relates to the foregoing lubricating oil composition wherein (A) the partial ester of a polyhydric alcohol and a carboxylic acid is a partial ester of trimethylolpropane and a monovalent carboxylic acid.

[0011] The present invention also relates to the foregoing lubricating oil composition further comprising (B) a poly (meth)acrylate compound composed of a structural unit represented by formula (I) below, in an amount of 0.01 to 20 percent by mass:



(I)

wherein R^1 is hydrogen or methyl and R^2 is a hydrocarbon group having 1 to 30 carbon atoms.

[0012] The present invention also relates to the foregoing lubricating oil composition wherein the composition has a traction coefficient of 0.013 or less.

[0013] The present invention also relates to the foregoing lubricating oil composition wherein the composition has a ratio of the traction coefficient to the 100°C kinematic viscosity (mm^2/s) is 1.2E-03 or less.

[0014] The present invention also relates to the foregoing lubricating oil composition wherein the composition has a -40°C Brookfield viscosity of 40,000 mPa·s or less.

Advantageous Effects of Invention

[0015] The lubricating oil composition of the present invention is low in traction coefficient and thus can maintain characteristics required for gear oil and attain energy saving properties and high efficiency when applied to manual, automatic or continuously variable transmissions of automobiles, or in industrial gear systems.

Description of Embodiment

[0016] A lubricating oil composition according to the present invention will be described below.

The lubricating oil composition of the present invention comprises an ester-based base oil comprising (A) a partial ester of a polyhydric alcohol and a carboxylic acid.

The alcohol constituting the ester-based base oil is a polyhydric alcohol. The carboxylic acid constituting the ester-based base oil may be a monobasic or polybasic acid. However, the ester-based base oil is necessarily a partial ester where at least part of the hydroxyl groups of the polyhydric alcohol remains unesterified.

[0017] The polyhydric alcohols may be those of usually dihydric to decahydric, preferably dihydric to hexahydric. Specific examples of the polyhydric alcohols of dihydric to decahydric include dihydric alcohols such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to pentadecamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to pentadecamer of propylene glycol), 1,3-propanedioil, 1,2-propanediol, 1,3-butanediol, 1,4-butanediol, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, 1,2-pentanediol, 1,3-pentanediol, 1,4-pentanediol, 1,5-pentanediol, and neopentyl glycol; polyhydric alcohols such as glycerin, polyglycerin (dimer to octamer thereof, such as diglycerin, triglycerin, and tetraglycerin), trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and dimers to octamers thereof, pentaerythritol and dimers to tetramers thereof, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensate, adonitol, arabitol, xylitol, and mannitol; saccharide such as xylose, arabinose, ribose, rhamnose, glucose, fructose, galactose, mannose, sorbose, cellobiose, maltose, isomaltose, trehalose, and sucrose; and mixtures thereof.

[0018] Among these polyhydric alcohols, preferable examples include those of dihydric to hexahydric, such as ethylene glycol, diethylene glycol, polyethylene glycol (trimer to decamer of ethylene glycol), propylene glycol, dipropylene glycol, polypropylene glycol (trimer to decamer of propylene glycol), 1,3-propanedioil, 2-methyl-1,2-propanediol, 2-methyl-1,3-propanediol, neopentyl glycol, glycerin, diglycerin, triglycerin, trimethylolalkanes (trimethylolethane, trimethylolpropane, trimethylolbutane) and dimers to tetramers thereof, pentaerythritol, dipentaerythritol, 1,2,4-butanetriol, 1,3,5-pentanetriol, 1,2,6-hexanetriol, 1,2,3,4-butanetetrol, sorbitol, sorbitan, sorbitol-glycerin condensate, adonitol, arabitol, xylitol, and mannitol, and mixtures thereof. More preferable examples include ethylene glycol, propylene glycol, neopentyl glycol, glycerin, trimethylolethane, trimethylolpropane, pentaerythritol, and sorbitan, and mixtures thereof. Particularly preferable examples include neopentyl glycol, trimethylolethane, trimethylolpropane and pentaerythritol, and mixtures thereof with the objective of attaining more excellent thermal/oxidation stability, and most preferable example is trimethylolpropane.

[0019] Among the acids constituting the ester-based base oil used in the present invention, examples of monobasic acids include fatty acids having usually 2 to 24, which may be straight-chain or branched and saturated or unsaturated. Specific examples include saturated fatty acids such as acetic acid, propionic acid, straight-chain or branched butanoic acid, straight-chain or branched pentanoic acid, straight-chain or branched hexanoic acid, straight-chain or branched heptanoic acid, straight-chain or branched octanonic acid, straight-chain or branched nonanoic acid, straight-chain or branched decanoic acid, straight-chain or branched undecanoic acid, straight-chain or branched dodecanoic acid, straight-chain or branched tridecanoic acid, straight-chain or branched tetradecanoic acid, straight-chain or branched pentadecanoic acid, straight-chain or branched hexadecanoic acid, straight-chain or branched heptadecanoic acid, straight-chain or branched octadecanoic acid, straight-chain or branched nonadecanoic acid, straight-chain or branched eicosanoic acid, straight-chain or branched heneicosanoic acid, straight-chain or branched docosanoic acid, straight-chain or branched tricosanoic acid, and straight-chain or branched tetracosanoic acid; unsaturated fatty acids such as acrylic acid, straight-chain or branched butenoic acid, straight-chain or branched pentenoic acid, straight-chain or branched hexenoic acid, straight-chain or branched heptenoic acid, straight-chain or branched octenoic acid, straight-chain or branched nonenoic acid, straight-chain or branched decenoic acid, straight-chain or branched undecenoic acid, straight-chain or branched dodecenoic acid, straight-chain or branched tridecenoic acid, straight-chain or branched tetradecenoic acid, straight-chain or branched pentadecenoic acid, straight-chain or branched hexadecenoic acid, straight-chain or branched heptadecenoic acid, straight-chain or branched octadecenoic acid, straight-chain or branched nonadecenoic acid, straight-chain or branched eicosenic acid, straight-chain or branched heneicosenic acid, straight-chain or branched docosenic acid, straight-chain or branched tircosenic acid, and straight-chain or branched tetracosenic acid; and mixtures thereof. Among these fatty acids, with the objective of further enhancing lubricity and treatability, preferred are saturated fatty acids having 3 to 20 carbon atoms, unsaturated fatty acids having 3 to 22 carbon atoms, and mixtures thereof. More preferred are saturated fatty acids having 4 to 18 carbon atoms, unsaturated fatty acids having 4 to 18 carbon atoms, and mixtures thereof. In view of oxidation stability, most preferred are saturated fatty acids having 4 to 18 carbon atoms.

[0020] Examples of polybasic acids include dibasic acids having 2 to 16 carbon atoms and trimellitic acid. The dibasic acids having 2 to 16 carbon atoms may be straight-chain or branched, or saturated or unsaturated. Specific examples include ethanedioic acid, propanedioic acid, straight-chain or branched butanedioic acid, straight-chain or branched pentanedioic acid, straight-chain or branched hexanedioic acid, straight-chain or branched heptanedioic acid, straight-chain or branched octanedioic acid, straight-chain or branched nonanedioic acid, straight-chain or branched decanedioic acid, straight-chain or branched undecanedioic acid, straight-chain or branched dodecandioic acid, straight-chain or branched tridecanedioic acid, straight-chain or branched tetradecanedioic acid, straight-chain or branched heptadecanedioic acid, and straight-chain or branched hexadecanedioic acid, straight-chain or branched straight-chain or branched hexenedioic acid, straight-chain or branched heptenedioic acid, straight-chain or branched octenedioic acid, straight-chain or branched nonenedioic acid, straight-chain or branched decenedioic acid, straight-chain or branched undecenedioic acid, straight-chain or branched dodecenedioic acid, straight-chain or branched tridecenedioic acid, straight-chain or branched tetradecenedioic acid, straight-chain or branched heptadecenedioic acid, straight-chain or branched hexadecenedioic acid, and mixtures thereof.

[0021] No particular limitation is imposed on the combination of an alcohol and an acid constituting the ester. For example, the following esters may be used in the present invention. These esters may be used alone or in combination.

(a) a partial ester of a polyhydric alcohol and a monobasic acid
(b) a partial ester of a polyhydric alcohol and a polybasic acid
(c) a mix partial ester of a polyhydric alcohol and a mixture of a monobasic acid and a polybasic acid

[0022] The percentage of the hydroxyl groups remaining unesterified in the whole hydroxyl groups in a polyhydric alcohol is preferably from 3 to 80 percent, more preferably from 5 to 70 percent, more preferably from 10 to 60 percent, most preferably from 15 to 50 percent. When the percentage of the remaining hydroxyl groups is less than 3 percent, the resulting lubricating oil composition may not be reduced sufficiently in traction coefficient. When the percentage is in excess of 80 percent, the resulting lubricating oil composition would be increased in friction caused by increased viscosity and be poor in oxidation stability.

[0023] Among these esters, preferred is (a) a partial ester of a polyhydric alcohol and a monobasic acid because of its excellent traction coefficient, more preferred is a diester of trimethylolpropane and a monobasic acid having 12 to 18 carbon atoms, and most preferred is a diester of trimethylolpropane and oleic acid.

[0024] The lubricating oil composition of the present invention contains the partial ester of a polyhydric alcohol and a carboxylic acid in an amount of 0.1 to 80 percent by mass, preferably 5 to 75 percent by mass, more preferably 10 to 70 percent by mass, more preferably 15 to 65 percent by mass, and most preferably 20 to 60 percent by mass on the basis of the total mass of the base oil. An ester content of less than 0.1 percent by mass may lead to a composition that can not satisfy the requirement of traction coefficient while an ester content of more than 80 percent by mass may lead to a composition that is increased in friction due to increased viscosity and deteriorated in oxidation stability.

[0025] The base oil of the lubricating oil composition of the present invention may contain base oil components other than the partial ester of a polyhydric alcohol and a carboxylic acid as long as the resulting mixed base oil has a kinematic viscosity at 100°C of 1 to 15 mm^2/s. Such base oil components may be any one or more types of mineral base oils, any one or more types of synthetic base oils, or mixtures thereof.

[0026] Specific examples of the mineral oil include those which can be produced by subjecting a lubricating oil fraction produced by vacuum-distilling an atmospheric distillation bottom oil resulting from atmospheric distillation of a crude oil, to any one or more treatments selected from solvent deasphalting, solvent extraction, hydrocracking, hydroisomerization, solvent dewaxing, catalytic dewaxing, and hydrorefining; wax-isomerized mineral oils; and those produced by isomerizing GTL WAX (Gas to Liquid Wax).

[0027] Specific examples of the synthetic base oil include polybutenes and hydrogenated compounds thereof; poly-α-olefins such as 1-octene oligomer and 1-decene oligomer, and hydrogenated compounds thereof; esters including full esters of the above-mentioned polyhydric alcohols and carboxylic acids, monoesters such as 2-ethylhexyl oleate, diesters such as ditridecyl glutarate, di-2-ethylhexyl adipate, diisodecyl adipate, ditridecyl adipate and di-2-ethylhexyl sebacate, and those other than (A) partial esters of polyhydric alcohols and carboxylic acids; aromatic synthetic oils such as alkylnaphthalenes, alkylbenzenes, and aromatic esters; and mixtures of the foregoing.

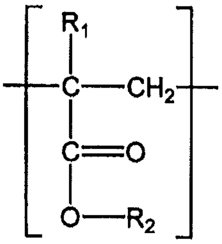
[0028] The lubricating base oil used in the present invention has a kinematic viscosity at 100°C of necessarily 1 to 15 mm^2/s, preferably 2 to 14 mm^2/s, more preferably 3 to 13 mm^2/s, more preferably 4 to 12 mm^2/s, particularly preferably 5 to 11 mm^2/s. When the 100°C kinematic viscosity of the lubricating base oil is greater than 15 mm^2/s, the resulting lubricating oil composition would be poor in low temperature viscosity characteristics. Meanwhile, when the 100°C kinematic viscosity is less than 1 mm^2/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss of the lubricating base oil.

[0029] No particular limitation is imposed on the viscosity index of the lubricating base oil used in the present invention. However, the viscosity index is preferably 80 or greater, more preferably 90 or greater, particularly preferably 110 or greater. A viscosity index of 80 or greater renders it possible to produce a composition exhibiting excellent viscosity characteristics from low to high temperatures.

[0030] The lubricating oil composition of the present invention contains preferably (B) a poly(meth)acrylate compound having a structure unit represented by formula (I) below.

This poly(meth) acrylate compound has functions as a viscosity index improver and/or a pour point depressant. The term "poly(meth)acrylate compound" used herein refers collectively to polyacrylate compounds and polymethacrylate compounds.

[0031]



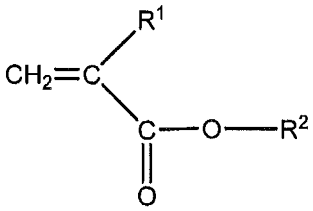
$$-\left[\begin{array}{l} \;R_1 \\ \;| \\ -C-CH_2- \\ \;| \\ \;C=O \\ \;| \\ \;O-R_2 \end{array}\right]-$$

(I)

(In formula (I), R_1 is hydrogen or methyl, and R_2 is a hydrocarbon group having 1 to 30 carbon atoms.)

[0032] (B) the poly(meth)acrylate compound is a polymer of a polymeric monomer containing a (meth)acrylate monomer (hereinafter referred to as "Monomer M-1") represented by formula (1) below.

[0033]



(1)

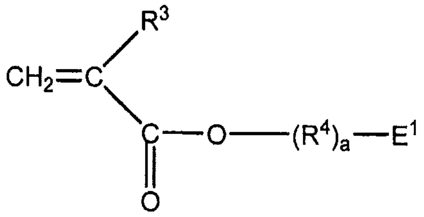
[0034] In formula (1) above, R^1 is hydrogen or methyl and R^2 is a straight-chain or branched hydrocarbon group having 1 to 30 carbon atoms.

Specific examples of the straight-chain or branched hydrocarbon group having 1 to 30 carbon atoms for R^2 include alkyl groups, which may be straight-chain or branched, such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, hexadecyl, and octadecyl groups; and alkenyl groups, which may be straight-chain or branched and the position of which the double bond may vary, such as butenyl, pentenyl, hexenyl, heptenyl, octenyl, nonenyl, decenyl, undecenyl, dodecenyl, tetradecenyl, hexadecenyl, and octadecenyl groups.

[0035] Typical examples of the poly(meth)acrylate compound include so-called non-dispersant type poly(meth)acrylates produced by homopolymerizing Monomer M-1 or copolymerizing two or more types of Monomers M-1.

[0036] The poly(meth)acrylate compound may be so-called dispersant type poly(meth)acrylates produced by copolymerizing Monomer M-1 with one or more monomers selected from the group consisting of (meth)acrylate monomers represented by formula (2) below (hereinafter referred to as "Monomer M-2") and monomers represented by formula (3) below (hereinafter referred to as "Monomer M-3").

[0037]



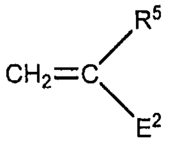
(2)

[0038] In formula (2) above, R^3 is hydrogen or methyl, R^4 is an alkylene group having 1 to 18 carbon atoms, E^1 is an amine residue or heterocyclic residue having 1 or 2 nitrogen atoms and 0 to 2 oxygen atoms, and a is an integer of 0 or 1.

[0039] Specific examples of alkylene groups having 1 to 18 carbon atoms for R^4 include ethylene, propylene, butylene, pentylene, hexylene, heptylene, octylene, nonylene, decylene, undecylene, dodecylene, tridecylene, tetradecylene, pentadecylene, hexadecylene, heptadecylene and octadecylene groups, all of which may be straight-chain or branched.

[0040] Specific examples of the amine residue or heterocyclic residue represented by E^1 include dimethylamino, diethylamino, dipropylamino, dibutylamino, anilino, toluidino, xylidino, acetylamino, benzoilamino, morpholino, pyrrolyl, pyrrolino, pyridyl, methylpyridyl, pyrolidinyl, piperidinyl, quinonyl, pyrrolidonyl, pyrrolidono, imidazolino and pyrazino groups.

[0041]



(3)

[0042] In formula (3), R^5 is hydrogen or methyl, and E^2 is an amine residue or heterocyclic residue having 1 or 2 nitrogen atoms and 0 to 2 oxygen atoms.

Specific examples of the amine residue or heterocyclic residue represented by E^2 include dimethylamino, diethylamino, dipropylamino, dibutylamino, anilino, toluidino, xylidino, acetylamino, benzoilamino, morpholino, pyrrolyl, pyrrolino, pyridyl, methylpyridyl, pyrolidinyl, piperidinyl, quinonyl, pyrrolidonyl, pyrrolidono, imidazolino and pyrazino groups.

[0043] The amine residue and heterocyclic residue in formulas (2) and (3) refer to a monovalent group derived by removing hydrogen from the amino group of an amine and a monovalent group derived by removing hydrogen bonded to the carbon constituting the heterocycle, from a molecule having a heterocyclic structure, respectively.

[0044] Specific preferable examples of Monomer-M-2 and Monomer M-3 include
dimethylaminomethylmethacrylate,
diethylaminomethylmethacrylate,
dimethylaminoethylmethacrylate,
diethylaminoethylmethacrylate,
2-methyl-5-vinylpyridine,
morpholinomethylmethacrylate,
morpholinoethylmethacrylate,
N-vinylpyrrolidone, and mixtures thereof.

[0045] No particular limitation is imposed on the copolymerization molar ratio of Monomer M-1 and Monomers M-2 and M-3 in a copolymer. However, M-1:M-2 and M-3 is preferably from 99:1 to 80:20, more preferably 98:2 to 85:15, more preferably 95:5 to 90:10.

[0046] No particular limitation is imposed on the method of producing (B) the poly(meth)acrylate compound, which, for example, is generally produced with ease by radical-solution polymerization of Monomer M-1 alone or a mixture of Monomer M-1 and Monomers M-2 and M-3 in the presence of a polymerization initiator such as benzoyl peroxide.

[0047] The weight average molecular weight (Mw) of (B) the poly (meth) acrylate compound is preferably 5,000 or greater, more preferably 10,000 or greater, more preferably 20,000 or greater, particularly preferably 30,000 or greater, and most preferably 40,000 or greater. The weight average molecular weight (Mw) is preferably 400,000 or less, more preferably 300,000 or less, more preferably 200, 000 or less, and particularly preferably 100,000 or less.
A weight average molecular weight of less than 5,000 leads to an insufficient improvement in viscosity index and would increase the production cost of the composition. A weight average molecular weight of greater than 400,000 would deteriorate the shear stability or storage stability of the resulting composition.

[0048] The PSSI (permanent shear stability index) of the poly(meth)acrylate compound is preferably 40 or less, more preferably from 5 to 40, more preferably from 10 to 35, particularly preferably from 15 to 30, and most preferably from 20 to 25. When the PSSI is greater than 40, the resulting composition would be poor in shear stability while when the PSSI is less than 5, a sufficient improvement in viscosity index would not be attained and thus a rise in the production cost of the composition would be incurred.

[0049] The term "PSSI" used herein denotes the permanent shear stability index of a polymer calculated on the basis of the data measured with ASTM D 6278-02 (Test Method for Shear Stability of Polymer Containing Fluids Using a European Diesel Injector Apparatus) in conformity with ASTM D 6022-01 (Standard Practice for Calculation of Permanent Shear Stability Index).

[0050] The lubricating oil composition of the present invention contains (B) the poly(meth)acrylate compound in an amount of preferably from 0.01 to 20 percent by mass, more preferably from 0.03 to 10 percent by mass, more preferably from 0.06 to 5 percent by mass, particularly preferably from 0.1 to 3 percent by mass on the basis of the total mass of the composition. A content of less than 0.01 percent by mass would lead to a failure to obtain a predetermined viscosity index improvement effect while a content of more than 20 percent by mass would leads to a composition having poor shear stability.

[0051] The lubricating oil composition of the present invention may be blended with various additives such as extreme pressure additives, ashless dispersants, metallic detergents, friction modifiers, anti-oxidants, corrosion inhibitors, viscosity index improvers other than the above-described Component (B), rust inhibitors, demulsifiers, metal deactivators, pour point depressants, seal swelling agents, anti-foaming agents, and dyes, alone or in combination in order to further enhance the properties of the composition or impart the composition with properties required for various lubricating oils.

[0052] The lubricating oil composition of the present invention may be blended with at least one type of phosphorus extreme pressure additive selected from phosphorous acid, phosphorus acid monoesters, phosphorus acid diesters, phosphorus acid triesters, and salts thereof; at least one type of sulfur extreme pressure additive selected from sulfurized fats and oils, sulfurized olefins, dihydrocarbyl polysulfides, dithiocarbamates, thiaziazoles, andbenzothiazoles; and/or at least one type of phosphorus-sulfur extreme pressure additive selected from thiophosphorus acids, thiophosphorus acid monoesters, thiophosphorus acid diesters, thiophosphorus acid triesters, dithiophosphorus acid, dithiophosphorus acid monoesters, dithiophosphorus acid diesters, dithiophosphorus acid triesters, trithiophosphorus acid, trithiophosphorus acid monoesters, trithiophosphorus acid diesters, trithiophosphorus acid triesters, and salts thereof.

[0053] Examples of the ashless dispersants include ashless dispersants such as succinimides, benzylamines and polyamines, each having a hydrocarbon group having 40 to 400 carbon atoms, and/or boron compound derivatives thereof. The content of the ashless dispersants is usually from 0.01 to 15 percent by mass on the basis of the total mass of the composition.

[0054] Examples of metallic detergents include those such as alkaline earth metal sulfonates, alkaline earth metal phenates, alkaline earth metal salicylates. The content of the metallic detergents is usually from 0.01 to 10 percent by mass, preferably from 0.1 to 5 percent by mass.

[0055] The friction modifiers may be any compounds that have been generally used as friction modifiers for lubricating oils. Specific examples include amine compounds, imide compounds, fatty acid esters, fatty acid amides, and fatty acid metal salts, each having per molecule at least one alkyl or alkenyl group having 6 to 30 carbon atoms, particularly a straight-chain alkyl or alkenyl group having 6 to 30 carbon atoms. Alternatively, organic molybdenum compounds such as molybdenum dithiophosphate and molybdenum dithiocarbamate may also be used. The content of the friction modifiers is usually from 0.01 to 5.0 percent by mass on the basis of the total mass of the composition.

[0056] The anti-oxidants may be any anti-oxidants that have been usually used in lubricating oils, such as phenolic or aminic compounds. Specific examples of the anti-oxidant include alkylphenols such as 2-6-di-tert-butyl-4-methylphenol; bisphenols such as methylene-4,4-bisphenol(2,6-di-tert-butyl-4-methylphenol); naphthylamines such as phenyl-α -naphthylamine; dialkyldiphenylamines; zinc dialkyldithiophosphoric acids such as di-2-ethylhexyldithiophosphoric acid; and esters of (3,5-di-tert-butyl-4-hydroxyphenyl)fatty acid (propionic acid) or (3-methyl-5-tert-butyl-4-hydroxyphenyl)fatty acid (propionic acid) with a monohydric or polyhydric alcohol such as methanol, octanol, octadecanol, 1,6-hexanediol, neopentyl glycol, thiodiethylene glycol, triethylene glycol and pentaerythritol. The content of the anti-oxidant is usually from 0.01 to 5 percent by mass on the basis of the total mass of the lubricating oil composition.

[0057] Examples of corrosion inhibitors include benzotriazole-, tolyltriazole-, thiadiazole-, and imidazole-type compounds.

[0058] Examples of viscosity index improvers other than Component (B) include non-dispersant- or dispersant-type ethylene-α-olefin copolymers and hydrogenated compounds thereof; polyisobutylenes or hydrogenated compounds thereof; styrene-diene hydrogenated copolymers; styrene-maleic anhydride ester copolymers; and polyalkylstyrenes.

[0059] Examples of rust inhibitors include petroleum sulfonates, alkylbenzene sulfonates, dinonylnaphthalene sulfonates, alkenyl succinic acid esters, and polyhydric alcohol esters.

[0060] Examples of demulsifiers include polyalkylene glycol-based non-ionic surfactants such as polyoxyethylenealkyl ethers, polyoxyethylenealkylphenyl ethers, and polyoxyethylenealkylnaphthyl ethers.

[0061] Examples of metal deactivators include imidazolines, pyrimidine derivatives, alkylthiadiazoles, mercaptobenzothiazoles, benzotriazoles and derivatives thereof, 1,3,4-thiadiazolepolysulfide, 1,3,4-thiadiazolyl-2,5-bisdialkyldithiocarbama te, 2-(alkyldithio)benzoimidazole, and β-(o-carboxybenzylthio)propionitrile.

[0062] The pour point depressants may be any of the known pour point depressants selected depending on the type of lubricating base oil but are preferably polymethacrylates having a weight average molecular weight of 80,000 to 200,000.

[0063] The anti-foaming agents may be any compounds that have been usually used as anti-foaming agents for lubricating oils. Examples of such anti-foaming agents include silicones such as dimethylsilicone and fluorosilicone.

[0064] The seal swelling agents may be any compounds that have been usually used as seal swelling agents for lubricating oils. Examples of such seal swelling agents include ester-, sulfur- and aromatic-based seal swelling agents.

[0065] The dyes may be any compounds that have been usually used and may be blended in any amount.

[0066] When these additives are blended with the lubricating oil composition of the present invention, the content of each additive is usually from 0.0005 to 5 percent by mass on the basis of the total mass of the composition except for the additives the amounts of which are specified above.

[0067] The lubricating oil composition of the present invention is desirously adjusted to have a kinematic viscosity at 100°C of necessarily 1 to 20 mm^2/s, preferably 2 to 15 mm^2/s, more preferably 3 to 13 mm^2/s, more preferably 4 to 12 mm^2/s, particularly preferably 5 to 11 mm^2/s. When the 100°C kinematic viscosity of the lubricating oil composition is greater than 20 mm^2/s, the composition would be poor in low temperature viscosity characteristics. Meanwhile, when the 100°C kinematic viscosity is less than 1 mm^2/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss.

[0068] The lubricating oil composition of the present invention has a traction coefficient of preferably 0.013 or less, more preferably 0.010 or less, more preferably 0.008 or less, particularly preferably 0.006 or less. A traction coefficient of greater than 0.013 would lead to a composition that fails to exhibit energy saving properties due to increased friction.

[0069] The lubricating oil composition of the present invention has a ratio of traction coefficient to 100°C kinematic viscosity (mm^2/s) of preferably 1.2E-03 or less, more preferably 1.1E-03 or less, more preferably 1.0E-03 or less, particularly preferably 9.5E-04 or less. A ratio of traction coefficient to 100°C kinematic viscosity (mm^2/s) of greater than 1.2E-03 would lead to a composition that fails to exhibit energy saving properties due to increased friction.

[0070] No particular limitation is imposed on the kinematic viscosity at 40°C of the lubricating oil composition of the present invention, which is, however, preferably from 10 to 100 mm^2/s, more preferably from 15 to 90 mm^2/s, more preferably from 20 to 80 mm^2/s, particularly preferably from 25 to 70 mm^2/s. When the 40°C kinematic viscosity of the lubricating oil composition is greater than 100 mm^2/s, the resulting composition would be poor in low temperature viscosity characteristics. Meanwhile, when the 40°C kinematic viscosity is less than 10 mm^2/s, the resulting lubricating oil composition would be poor in lubricity due to its insufficient oil film formation at lubricating sites and would be large in evaporation loss.

[0071] No particular limitation is imposed on the Brookfield viscosity (BF viscosity) at -40°C of the lubricating oil composition of the present invention, which is, however, preferably 40,000 mPa·s or less, more preferably 35,000 mPa·s or less, more preferably 30,000 mPa·s or less, particularly preferably 25,000 mPa·s or less. When the -40°C BF viscosity is greater than 40, 000 mPa·s, the composition would be poor in low temperature viscosity characteristics and thus be adversely affected in terms of energy saving properties. The term "BF viscosity" used herein denotes the viscosity measured in accordance with "Gear oil low temperature viscosity determination method" prescribed in JPI-5S-26-85.

[0072] No particular limitation is imposed on the viscosity index of the lubricating oil composition of the present invention, which is, however, preferably 120 or greater, more preferably 140 or greater, particularly preferably 160 or greater. A viscosity index of 120 or greater renders it possible to produce a composition exhibiting excellent viscosity characteristics from low to high temperatures.

[0073] No particular limitation is imposed on the evaporation loss of the lubricating oil composition of the present invention. However, the NOACK evaporation loss is preferably from 10 to 50 percent by mass, more preferably from 20 to 40 percent by mass, particularly preferably from 22 to 35 percent by mass. The use of a lubricating oil composition having a NOACK evaporation loss adjusted within the above ranges renders it possible to attain both low temperature characteristics and anti-wear properties. The term "NOACK evaporation loss" used herein denotes the evaporation loss measured in accordance with CEC L-40-T-87.

[0074] The lubricating oil composition of the present invention is excellent in energy saving properties and high in efficiency, and can contribute to an improving in automobile fuel efficiency and energy saving in factories when used in manual, automatic or continuously variable transmissions of automobiles, or in industrial gear systems.

Examples

[0075] Hereinafter, the present invention will be described in more details by way of the following examples and comparative examples, which should not be construed as limiting the scope of the invention.

(Examples 1 and 2, Comparative Examples 1 to 5)

[0076] Lubricating oil compositions according to the present invention (Examples 1 and 2) were prepared in accordance with the formulations set forth in Table 1 below. The traction coefficient of each composition was measured and the results are also set forth in Table 1.
Lubricating oil compositions for comparison (Comparative Examples 1 to 5) were prepared in accordance with the formulations set forth in Table 1 below. The traction coefficient of each composition was measured and the results are also set forth in Table 1.

[Measurement of traction coefficient]

[0077] Traction coefficient was measured under the following conditions using a film EHL tester*.
(*) described in Tribology International (March 2007) by R. Kapadia et al.

(Test Conditions)

[0078]

Test piece : SUJ2
Oil temperature : 100°C
Surface pressure : 0.514 GPa
Slip ratio : 100%

[0079] As set forth in Table 1, the compositions each comprising a partial ester of a polyhydric alcohol and a carboxylic acid (Examples 1 and 2) are apparently lower in traction coefficient than those comprising each a full ester of a polyhydric alcohol (Comparative Examples 1 to 3), that comprising a trimellitic acid ester (Comparative Example 4) and that comprising PAO (Comparative Example 5).

[0080]

Table 1

		Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Base oil cunstitution (basis of total base oil mass)								
(A) Ester base oil 1 [1)]	mass%	43	43					
Ester base oil 2 [2)]	mass%	57	57					
Ester base oil 3 [3)]	mass%			100	100			
Ester base oil 4 [4)]	mass%					100		
Ester base oil 5 [5)]	mass%						100	
PAD [6)]	mass%							100
Additives (basis of total composition mass)								
(B) PMA [7)]	mass%		0.5		0.5			
Gear oil additive package [8)]	mass%	15.8	15.8	15.8	15.8	15.8	15.8	15.8
Kinematic viscosity 40°C	mm^2/s	47.8	47.9	48.5	48.6	48.5	83.1	60
100°C	mm^2/s	9.6	9.6	9.4	9.5	9.2	9.3	9.4
Viscosity index		190	190	183	183	176	86	138
BF viscosity -40°C	mPa · s	113,000	19,000	>1, 000, 000	58,000	310,000		40
Traction coefficient		0.009	0.009	0.014	0.014	0.012	0.026	0.021

(continued)

		Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Traction coefficient /100°C Kinematic viscosity		9.4E-04	9.4E-04	1.5E-03	1.5E-03	1.3E-03	2.8E-03	2.2E-03

1) Ester base oil 1: diester of trimethylolpropane and oleic acid (40°C kinematic viscosity: 541.7, 100°C kinematic viscosity: 55.3, viscosity

2) Ester base oil 2: monoester of oleic acid and 2-ethylhexyl alcohol (40°C kinematic viscosity: 8.7, 100°C kinematic viscosity: 2.7, viscosity index: 174)

3) Ester base oil 3: triester of trimethylolpropane and oleic acid (40°C kinematic viscosity: 48.1, 100°C kinematic viscosity: 9.5, viscosity index: 187)

4) Ester base oil 4: triester of trimethylolpropane and stearic acid (40°C kinematic viscosity: 47.2, 100°C kinematic viscosity: 9.3, viscosity index: 183)

5) Ester base oil 5: triester of trimellitic acid and 2-ethylhexyl alcohol (40°C kinematic viscosity: 89, 100°C kinematic viscosity: 9.6, viscosity index: 79)

6) PA0: poly-α-oletin (mixture of PA01: PA02=95:5; PA01<40°C kinematic viscosity: 64.89, 100°C kinematic viscosity: 9.912, viscosity index: 1 PA02<40°C kinematic viscosity: 18.33, 100°C kinematic viscosity: 4.081, viscosity index: 124>)

7) PMA: polymethacrylate (weight average molecular weight: 60,000, n-C12, C14, C16, C18 alkyl)

8) Gear oil additive package (containing phosphorus acid ester, thiophosphoric acid, oletin sulfide) Unit of each kinematic viscosity is mm^2 /s

Industrial Applicability

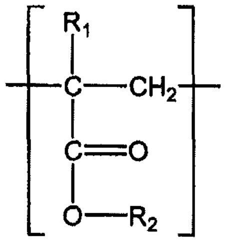
[0081] The lubricating oil composition of the present invention is extremely useful because it is low in traction coefficient and thus can maintain characteristics required for gear oil and attain energy saving properties and high efficiency when applied to manual, automatic or continuously variable transmissions of automobiles, or in industrial gear systems.

Claims

1. A lubricating oil composition having a low traction coefficient, comprising a lubricating base oil containing (A) a partial ester of a polyhydric alcohol and a carboxylic acid in an amount of 0.1 to 80 percent by mass on the basis of the total mass of the base oil and having a kinematic viscosity at 100°C of 1 to 15 mm²/s, the composition having a kinematic viscosity at 100°C of 1 to 20 mm²/s.

2. The lubricating oil composition according to claim 1 wherein (A) the partial ester of a polyhydric alcohol and a carboxylic acid is a partial ester of trimethylolpropane and a monovalent carboxylic acid.

3. The lubricating oil composition according to claim 1 or 2, further comprising (B) a poly(meth)acrylate compound composed of a structural unit represented by formula (I) below, in an amount of 0.01 to 20 percent by mass:



$$\left[-\overset{\displaystyle R_1}{\underset{\displaystyle \underset{\displaystyle O-R_2}{C=O}}{C}}-CH_2- \right] \quad (I)$$

wherein R^1 is hydrogen or methyl and R^2 is a hydrocarbon group having 1 to 30 carbon atoms.

4. The lubricating oil composition according to any of claims 1 to 3, wherein the composition has a traction coefficient of 0.013 or less.

5. The lubricating oil composition according to any one of claims 1 to 4, wherein the composition has a ratio of the traction coefficient to the 100°C kinematic viscosity (mm²/s) is 1.2E-03 or less.

6. The lubricating oil composition according to any one of claims 1 to 5, wherein the composition has a -40°C Brookfield viscosity of 40,000 mPa·s or less.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004907

A. CLASSIFICATION OF SUBJECT MATTER
C10M105/40(2006.01)i, *C10M169/04*(2006.01)i, *C10M145/14*(2006.01)n, *C10N20/00*(2006.01)n, *C10N20/02*(2006.01)n, *C10N30/00*(2006.01)n, *C10N30/06*(2006.01)n, *C10N40/04*(2006.01)n

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10M105/40, C10M169/04, C10M145/14, C10N20/00, C10N20/02, C10N30/00, C10N30/06, C10N40/04

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2-155987 A (Idemitsu Kosan Co., Ltd.), 15 June 1990 (15.06.1990), & EP 373454 A1	1-6
A	JP 63-213596 A (Idemitsu Kosan Co., Ltd.), 06 September 1988 (06.09.1988), (Family: none)	1-6
A	JP 62-283195 A (Toa Nenryo Kogyo Kabushiki Kaisha), 09 December 1987 (09.12.1987), & US 5075024 A & EP 275313 A1 & WO 1987/007635 A1 & DE 3788118 T & DE 3788118 D & CA 1293515 A	1-6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 06 November, 2009 (06.11.09)	Date of mailing of the international search report 24 November, 2009 (24.11.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004907

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 62-283192 A (Toa Nenryo Kogyo Kabushiki Kaisha), 09 December 1987 (09.12.1987), & US 4889650 A & EP 295304 A1 & WO 1987/007634 A1 & DE 3785031 D & DE 3785031 T & CA 1282403 A	1-6
A	JP 2004-300317 A (Kyodo Yushi Co., Ltd.), 28 October 2004 (28.10.2004), (Family: none)	1-6

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004907

Box No. II **Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 1-6
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Since claims 1-6 include lubricating oil compositions having low traction coefficients which are not fully supported by the description, relevant prior art cannot be specified.
(continued to extra sheet)

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III **Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004907

Continuation of Box No.II-2 of continuation of first sheet(2)

Claims 1-6 describe lubricating oil compositions having low traction coefficients which each comprise as the base oil a lubricating oil containing a partial ester of a polyhydric alcohol with a carboxylic acid in an amount of 0.1 to 80wt% relative to the whole base oil and exhibiting a kinematic viscosity of 1 to 15mm^2/s at 100°C and which exhibit kinematic viscosities of 1 to 20mm^2/s at 100°C. However, only lubricating oil compositions which comprise base oils containing specific esters realize low traction coefficients (of 0.013 or below). Additionally, the description does not disclose how to lower the traction coefficient, so that it cannot specifically be imagined what compositions of base oil realize such low traction coefficients. Further, the properties of a base oil depends on the kinds of components and so on. Thus, it cannot be presumed that all base oils that contain a partial ester of a polyhydric alcohol with a carboxylic acid in an amount of 0.1 to 80wt% relative to the whole base oil and that exhibit a kinematic viscosity of 1 to 15mm^2/s at 100°C exert an effect (lowering in traction coefficient) similar to that of specific base oils which are specifically disclosed in the description.

Thus, lubricating oil compositions except those comprising specifically disclosed base oils are not fully supported by the description.

Therefore, lubricating oil compositions of claims 1-6 which are not specifically disclosed in the description cannot be determined for relevancy to prior art.

Consequently, this international search report covers only lubricating oil compositions of claims 1-6 which each comprise as the base oil a lubricating oil containing diester of trimethylolpropane with oleic acid or monoester of 2-ethylhexyl alcohol with oleic acid and exhibiting a kinematic viscosity of 1 to 15mm^2/s at 100°C and which exhibit kinematic viscosities of 1 to 20mm^2/s.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 10213552 A **[0006]**
- JP 9068161 A **[0006]**