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Mori et al.(10) **Pub. No.: US 2020/0071634 A1**(43) **Pub. Date: Mar. 5, 2020**(54) **LUBRICATING OIL COMPOSITION**(71) Applicant: **ExxonMobil Research and Engineering Company**, Annandale, NJ (US)(72) Inventors: **Takafumi Mori**, Kawasaki-shi (JP);
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A lubricating oil composition which achieves extended anti-shudder durability without causing a decrease in the metal-to-metal friction coefficient, even when the viscosity of the composition is reduced. The lubricating oil composition includes (A) a lubricant base oil, (C) (C-1) a succinimide compound or boronated succinimide compound having a weight-average molecular weight of 4,000 to 7,000, (C-2) a succinimide compound or boronated succinimide compound having a weight-average molecular weight of more than 7,000 to 10,000, and (D) a phosphorus-based extreme pressure agent, the lubricating oil composition does not include zinc dithiophosphate and may optionally include a sulfur-based extreme pressure agent, provided that the content of sulfur-based extreme pressure agent is no more than 0.1 percent by weight of the lubricating oil composition.

LUBRICATING OIL COMPOSITION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is the National Phase entry of International Patent Application No. PCT/IB2017/001299 filed on Oct. 27, 2017, which claims priority to Japanese Patent Application No. 2016-210408 filed on Oct. 27, 2016 the entire contents of which are hereby incorporated by reference into this application.

FIELD

[0002] The present disclosure relates to a lubricating oil composition, especially suitable for use in an automobile transmission. More specifically, it concerns a lubricating oil composition for a non-stage transmission.

BACKGROUND

[0003] Lubricating oil compositions are widely used in the automotive field for internal combustion engines, automatic transmission, gear oil, etc. The demand for low-viscosity lubricating oil compositions has recently increased, in order to achieve fuel efficiency. In addition, as non-stage transmission (CTV) has been replacing stepped automatic transmission and becoming widely used, metal belt CVT, in which a metal belt and a pulley are used for power transmission, has become generally used.

[0004] One method of improving the fuel economy of non-stage transmission automobiles is expanding the operating conditions of the lock-up clutch, and it requires extension of the lock-up clutch shudder prevention lifespan. Nevertheless, if the quantity of the friction conditioner is increased, in order to extend the shudder prevention lifespan, the intermetallic friction coefficient between the metal belt and the pulley decreases, the belt grip performance decreases, and the torque transmission ability decreases. Considering such a trade-off between the shudder prevention and the intermetallic friction coefficient, compatibility of both sufficient torque and shudder prevention performance at a high level has been sought after. When the viscosity of a lubricating oil composition for transmission is lowered, satisfactory intermetallic friction coefficient cannot be achieved, nor can sufficiently large torque be secured.

[0005] Examples of conventional lubricating oil compositions for non-stage transmission are described in patent literature 1 to 5. JP 2006-056934 A (Patent literature 1) describes a lubricating oil composition which comprises a specific boron-free succinimide compound and a phosphorus compound, and does not comprise a zinc dialkyl dithiophosphate, which significantly increases the friction coefficient between the metal belt or chain and the pulley, is capable of maintaining a high friction coefficient over a long period of time, and does not cause clogging of the clutch plates. JP 2007-126541 A (Patent literature 2) describes a lubricant composition comprising a sulfonate-based detergent, a salicylates-based detergent and a boron-containing succinimide-based additive at specific quantities and specific quantity ratios, which maintains satisfactory torque transmission capacity and transmission properties and excels in its shudder prevention performance. JP 2009-215395 A (Patent literature 3) describes a lubricating oil composition comprising specific quantities of a boronated alkylsuccinimide and/or boronated alkenylsuccinimide hav-

ing a specific weight-average molecular weight, and a metallic detergent having a linear alkyl group, which has a high intermetallic friction coefficient and excellent transmission properties and shudder prevention performance. JP 2010-180278 A (Patent literature 4) describes a lubricating oil composition comprising specific quantities of at least one selected from a specific sulfolane derivative, calcium sulfonate and calcium phenate, and a specific viscosity index improver, which has both a high intermetallic friction coefficient and combines fuel efficiency, due to low viscosity, and component durability. JP 2000-355695 A (Patent literature 5) describes that by combining at least 4 additives, namely calcium salicylates, phosphorus anti-wear agent, friction conditioner and dispersion-type viscosity index improving agent, as essential components, both a high intermetallic friction coefficient and shudder prevention can be achieved.

CITATION LIST

Patent Literature

[PTL 1]

JP 2006-056934 A

[PTL 2]

JP 2007-126541 A

[PTL 3]

JP 2009-215395 A

[PTL 4]

JP 2010-180278 A

[PTL 5]

JP 2000-355695 A

SUMMARY

Technical Problem

[0006] In light of the above circumstances, the present disclosure may provide a lubricating oil composition, whose intermetallic friction coefficient does not decrease and which has extended shudder prevention lifespan, even if the viscosity thereof is lowered.

Solution to Problem

[0007] As a result of painstaking research, the inventors arrived at the subject matter of the present disclosure after discovering that the shudder prevention lifespan can be extended without decreasing the intermetallic friction coefficient, even at low viscosity, if two types of succinimide compounds or boronated succinimide compounds having specific weight-average molecular weights are combined as an ashless dispersant and used together with a phosphorus-based extreme pressure agent.

[0008] That is, the present disclosure is directed to a lubricating oil composition comprising

[0009] (A) a lubricant base oil,

[0010] (C) (C-1) a succinimide compound or boronated succinimide compound having a weight-average molecular weight of 4,000 to 7000, and (C-2) a succinimide compound or boronated succinimide compound having a weight-average molecular weight of more than 7,000 and not more than 10,000, and

[0011] (D) a phosphorus-based extreme pressure agent,

[0012] wherein the lubricating oil composition does not comprise zinc dithiophosphate, and the lubricating oil composition may optionally comprise a sulfur-based extreme pressure agent, provided that a content of the sulfur-based extreme pressure agent is not more than 0.1 percent by weight based on the lubricating oil composition.

[0013] Moreover, in order to improve fuel economy, the viscosity may be maintained at an elevated temperature (for example, 100° C.) while decreasing the viscosity at a low temperature (for example, 40° C.), which has an effect on the fuel economy, that is, a high viscosity index, but in conventional lubricating oil compositions for non-stage transmission, the polymer chains of the base oil and the viscosity index improver are broken by the mechanical shear, and as a result the high temperature viscosity decreases with operation.

[0014] The inventors discovered that by further specifying the constitutions of the lubricant base oil and the viscosity index improver in the above lubricating oil composition, the shear stability can be improved, in addition to an effect of extending the shudder prevention lifespan without decreasing the intermetallic friction coefficient.

[0015] That is, the present disclosure also includes a lubricating oil composition comprising

[0016] (A) a lubricant base oil,

[0017] (C) (C-1) a succinimide compound or a boronated succinimide compound having a weight-average molecular weight of 4,000 to 7,000, and (C-2) a succinimide compound or a boronated succinimide compound having a weight-average molecular weight of more than 7,000 and not more than 10,000, and

[0018] (D) a phosphorus-based extreme pressure agent,

[0019] wherein the lubricating oil composition does not contain zinc dithiophosphate, and the lubricating oil composition may optionally contain a sulfur-based extreme pressure agent, provided that a content of the sulfur-based extreme pressure agent is not more than 0.1 percent by weight based on the lubricating oil composition, the lubricating oil composition comprises, as a part or all of component (A), 5 to 30 percent by weight, based on a total weight of the lubricating oil composition, of a poly- α -olefin or α -olefin copolymer having a kinematic viscosity at 100° C. of 6 to 80 mm²/s, and the lubricating oil composition further comprises (B) a polymethacrylate having a weight-average molecular weight of 15,000 to 40,000.

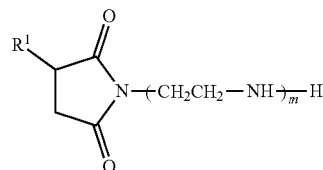
[0020] In addition, in some embodiments, the lubricating oil composition of the present disclosure may have at least one of following features (1) to (10).

[0021] (1) A part or all of component (C-1) and component (C-2) is a boronated succinimide compound.

[0022] (2) Each of component (C-1) and component (C-2) comprises 0.1 to 3 percent by weight of boron based on the weight of component (C-1) or component (C-2).

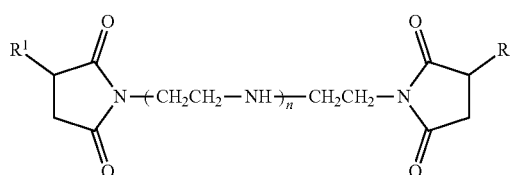
[0023] (3) The succinimide compound is represented by following formula (1) or (2):

[Chem. 1]



(1)

[Chem. 2]



(2)

wherein R¹ is each independently an alkyl or alkenyl group having 40 to 400 carbon atoms, m is an integer between 1 and 20, and n is an integer between 0 and 20.

[0024] (4) The lubricating oil composition has a kinematic viscosity at 100° C. of 3 to 10 mm²/s.

[0025] (5) The lubricating oil composition has a viscosity index of 150 or higher.

[0026] (6) The phosphorus-based extreme pressure agent (D) is at least one selected from acidic phosphate, acidic phosphite, phosphate, phosphite, and amine salts thereof, phosphoric acid, and phosphorus acid.

[0027] (7) The phosphorus-based extreme pressure agent (D) is at least one selected from acidic phosphate, acidic phosphite, phosphate, phosphite, and amine salts thereof, combined with at least one selected from phosphoric acid and phosphorus acid.

[0028] (8) The lubricating oil composition also comprises (E) a metallic detergent.

[0029] (9) The lubricating oil composition also comprises (F) an ether sulfolane compound.

[0030] (10) The lubricating oil composition is for a non-stage transmission.

[0031] In particular, the lubricating oil composition may comprise, as a part or all of component (A), 5 to 30 percent by weight, based on a total weight of the lubricating oil composition, of a poly- α -olefin or α -olefin copolymer having a kinematic viscosity at 100° C. of 6 to 80 mm²/s, and (E) an ether sulfolane compound. Compared with mineral oil, synthetic base oil has low affinity to the oil seal rubber called packing or gasket, and the affinity is lower as the base oil has a higher molecular weight, i.e., higher viscosity. When the affinity is low, the swelling property of the seal rubber decreases, and conversely it is easy to shrink. This causes the sealing to decrease and oil spill to occur. The lubricating oil composition of the present disclosure having the above features ensures that the seal rubber can sufficiently swell.

[0032] The lubricating oil composition of the present disclosure may be capable of extending the shudder prevention lifespan without decreasing the intermetallic friction

coefficient. This effect can be achieved even when the kinematic viscosity at 100° C. of the lubricating oil composition is lowered to about 5.0. In addition to the above effect, the lubricating oil compositions of the present disclosure can provide a lubricating oil composition having increased shear stability. Furthermore, it ensures that the seal rubber can sufficiently swell. The lubricating oil composition of the present disclosure can be suitably used especially as a lubricating oil composition for a non-stage transmission.

DESCRIPTION

[0033] Each component will now be described.

(A) Lubricant Base Oil

[0034] Different types of lubricant base oils can be used as the lubricant base oil in the lubricating oil compositions of the present disclosure. The lubricant base oil includes a mineral oil, a synthetic oil, or a mixture thereof. In particular, the lubricating oil composition may comprise, as a part or all of the lubricant base oil, 5 to 30 percent by weight, based on a total weight of the lubricating oil composition, of a poly- α -olefin or α -olefin copolymer having a kinematic viscosity at 100° C. of 6 to 80 mm²/s. The lower limit of the content of the poly- α -olefin or α -olefin copolymer may be 6 percent by weight, or even 8 percent by weight, and the upper limit may be 25 percent by weight, or even 20 percent by weight. If the content of the above base oil is below the above lower limit, there is a possibility that a satisfactory viscosity index, i.e., a combination of fuel efficiency and protection of the machine elements, cannot be achieved, and if it exceeds the above upper limit, there is a possibility that the shear stability may decrease and the rubber adaptability may deteriorate, i.e., the rubber shrinks.

[0035] The poly- α -olefin or α -olefin copolymer has a kinematic viscosity at 100° C. of from 6 to 80 mm²/s, from 8 to 80 mm²/s, from 8 to 60 mm²/s, or from 9 to 40 mm²/s. If the kinematic viscosity at 100° C. is below the above lower limit, a satisfactory viscosity index, i.e., a combination of fuel efficiency and protection of the machine elements, cannot be achieved, and if the kinematic viscosity at 100° C. exceeds the above upper limit, the shear stability decreases and the rubber adaptability deteriorates, i.e., the rubber shrinks.

[0036] The poly- α -olefin or α -olefin copolymer is a (co) polymer or (co)oligomer of α -olefin. Any poly- α -olefins or α -olefin copolymers may be used as the lubricant base oil, as long as they have the above kinematic viscosity. The α -olefin is selected, for example, from a C₂₋₁₄, or C₄₋₁₂, linear or branched olefinic hydrocarbons. Examples of the poly- α -olefin or α -olefin copolymer include 1-octene oligomer, 1-decene oligomer, ethylene-propylene oligomer, isobutene oligomer, and hydrogenated products thereof. Moreover, the poly- α -olefin or α -olefin copolymer may be manufactured using a metallocene catalyst. The weight-average molecular weight of the (co)polymer or (co)oligomer should only be such that the kinematic viscosity at 100° C. is within the above range. Its weight-average molecular weight may be, for example, from 1,000 to 10,000, or from 1,100 to 7,000. One type of poly- α -olefin or α -olefin copolymer may be used, or two or more types thereof may be used together.

[0037] The lubricating oil composition of the present disclosure may comprise other lubricant base oils in combination with the above poly- α -olefin or α -olefin copolymer. The other lubricant base oils include, but are not limited to, mineral oil-based base oils and synthetic base oils other than the above poly- α -olefin or α -olefin copolymer.

[0038] Examples of the mineral oil-based base oil include paraffinic or naphthenic lubricant base oils, obtained by distilling a crude oil at a normal atmospheric pressure and under vacuum to prepare a lubricating oil fraction and subjecting the lubricating oil fraction to a suitable combination of purification treatments such as solvent deasphalting, solvent extraction, hydrogenolysis, solvent dewaxing, catalytic dewaxing, hydrorefining, sulfuric acid treatment and clay treatment, and lubricant base oils obtained by isomerizing a wax obtained by solvent dewaxing and dewaxing the isomerized product. The kinematic viscosity of the mineral oil-based base oil is, but is not limited to, 1 to 5 mm²/s in order to obtain a low-viscosity lubricating oil composition.

[0039] Examples of the synthetic base oil include isoparaffins, alkylbenzenes, alkyl-naphthalenes, monoesters, diesters, polyol esters, polyoxyalkylenglycols, dialkyldiphenyl ethers, polyphenyl ethers, and GTL base oils. No particular restrictions are placed on the kinematic viscosity of the synthetic base oil. Furthermore, a poly- α -olefin or α -olefin copolymer having a kinematic viscosity at 100° C. of less than 6 mm²/s or more than 80 mm²/s can also be used. In order to obtain a low-viscosity lubricating oil composition, the kinematic viscosity of the synthetic base oil may be from 1 to 6 mm²/s.

[0040] The other base oils used in combination with the poly- α -olefin or α -olefin copolymer may be used alone or two or more types thereof may be used together. When two or more types thereof are used, two or more types of mineral oil-based base oils may be used, two or more types of synthetic base oils may be used, or a combination of a mineral oil-based base oil and a synthetic base oil may be used. Among them, the use of a single mineral oil-based base oil, the use of two or more types of mineral oil-based base oils, the use of a single synthetic base oil having a kinematic viscosity at 100° C. of not less than 1 mm²/s and less than 6 mm²/s, and the use of two or more types of synthetic base oils having a kinematic viscosities at 100° C. of not less than 1 mm²/s and less than 6 mm²/s may be used.

[0041] Moreover, in order to obtain a low-viscosity lubricating oil composition, the whole lubricant base oil may have a kinematic viscosity at 100° C. of from 2 to 7 mm²/s, from 2.3 to 6 mm²/s, or from 2.5 to 5.6 mm²/s.

(B) Viscosity Index Improver

[0042] The lubricating oil composition of the present disclosure may also comprise a viscosity index improver. The lubricating oil composition may comprise a polymethacrylate having a weight-average molecular weight of 15,000 to 40,000 as the viscosity index improver. The lower limit of the weight-average molecular weight is 17,000, or even 18,000. The upper limit of the weight-average molecular weight is 38,000, or even 6,000. If the weight-average molecular weight is less than the above lower limit, the effect of the viscosity index improver is insufficient, and if the weight-average molecular weight is more than the above upper limit, the effect of viscosity index improvement is achieved, but the shear stability deteriorates. The content of

the polymethacrylate may be, but is not limited to, from 0.1 to 20 percent by weight, from 0.1 to 15 percent by weight, or from 2 to 10 percent by weight, based on the lubricating oil composition.

[0043] One type of the polymethacrylate may be used alone or two or more types thereof may be used in combination. When two or more types thereof are used in combination, no restrictions are placed on the contents thereof. The total content of the polymethacrylate(s) is from 0.1 to 20 percent by weight, from 0.1 to 15 percent by weight, or from 2 to 10 percent by weight, based on the lubricating oil composition.

[0044] The lubricating oil composition of the present disclosure may also comprise other viscosity index improvers in combination with the polymethacrylate. Examples of other viscosity index improvers include polymethacrylate having a weight-average molecular weight of less than 15,000, polymethacrylate having a weight-average molecular weight of more than 40,000, polyisobutylene and hydrogenated products thereof, hydrogenated styrene-diene copolymer, styrene-maleic anhydride ester copolymer and polyalkylstyrene. If other viscosity index improvers are contained, the content thereof is from 0.1 to 15 percent by weight based on the lubricating oil composition.

(C) Succinimide Compound or Boronated Succinimide Compound

[0045] The lubricating oil composition of the present disclosure comprises, as an ashless dispersant, two types of specific succinimide compounds or boronated succinic acid imide compounds. In other words, the lubricating oil composition comprises (C-1) a succinimide compound or a boronated succinimide compound having a weight-average molecular weight of from 4,000 to 7,000, or from 5,000 to 7,000, and (C-2) a succinimide compound or a boronated succinimide compound having a weight-average molecular weight of more than 7,000 and not more than 10,000, or from 7,100 to 9,600. Hereinafter, above component (C-1) is referred to as “the 1st succinic acid imide compound” and above component (C-2) is referred to as “the 2nd succinic acid imide compound.” A part or all of at least one of component (C-1) and component (C-2) may be a boronated succinimide compound. Furthermore, both component (C-1) and component (C-2) may be a boronated succinimide compound.

[0046] The content of component (C) in the composition is from 0.5 to 3 percent by weight, from 0.6 to 2.5 percent by weight, or from 0.9 to 2 percent by weight, based on the total weight of the composition. If the content of component (C) is less than the above lower limit, the shudder prevention may not be secured. If the content of component (C) is more than the above upper limit, the viscosity may increase at a low temperature.

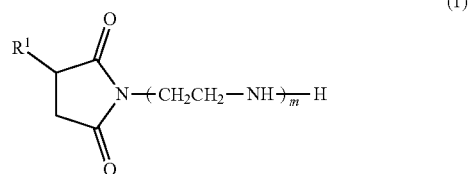
[0047] The weight ratio of component (C-1) to component (C-2), i.e., (C-2)/(C-1), may be, but is not limited to, from 1 to 10, from 1.5 to 8, or from 2 to 6. By comprising these components at the above ratio range, both the friction coefficient and anti-shudder properties can be achieved. If the weight ratio of (C-2) exceeds the above upper limit, the quantity of component (C-1) is too small and the shudder prevention is insufficient at low temperatures, e.g., at 40° C., which is evident early in endurance testing. If the weight ratio of (C-2) is below the above lower limit, the properties

at high temperatures, e.g., at 120° C., are insufficient, which is evident early in endurance testing.

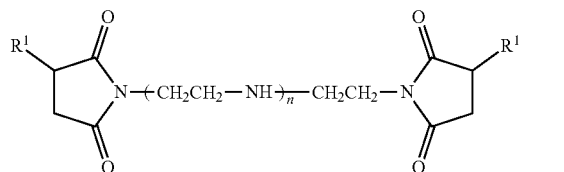
[0048] The 1st and 2nd succinimide compounds of the present disclosure may be a succinimide compound or boronated succinimide compound known publicly as an ashless dispersant. An example of a boronated succinimide compound is a product obtained by modifying (boronating) a succinimide compound containing in its molecule at least one alkyl or alkenyl group with a boron compound such as boric acid or a salt thereof. Examples of the alkyl or alkenyl group include olefins such as propylene, 1-butene, isobutylene, etc., oligomers thereof, co-oligomers of ethylene and propylene, etc.

[0049] More specifically, the succinimide compound is a compound obtained by adding succinic anhydride to polyamine. There are monotype succinimide compounds and bis-type succinimide compounds, and either can be used. The monotype succinimide compound can be represented by formula (1) below. The bis-type succinic acid imide compound can be represented by formula (2) below.

[Chem. 3]



[Chem. 4]



wherein R¹ is each independently an alkyl or alkenyl group having 40 to 400 carbon atoms, m is an integer of 1 to 20, and n is an integer of 0 to 20. In some embodiments, the succinimide compound may be a bis-type compound. As succinic acid imide compounds, a monotype succinimide compound and a bis-type succinimide compound can be used in combination, or two or more monotype succinimide compounds may be used in combination, or two or more bis-type succinimide compounds may be used in combination.

[0050] The boronated succinimide compound is a compound obtained by reacting a succinimide compound represented by the above formula with a boron compound. Examples of a boron compound include boric acid, boric anhydride, an ester of boric acid, boron oxide, boron halide, etc. One type of boronated succinimide compound may be used alone, or two or more types thereof may be used in combination.

[0051] In the lubricating oil composition of the present disclosure, a part or all of each of the 1st and 2nd succinimide compounds may be a boronated succinimide compound. Therefore, the 1st and 2nd succinimide compounds of the present disclosure may be selected from a single

succinimide compound which is not boronated, and two or more thereof, a single boronated succinimide compound, and two or more thereof, and a combination of one or more succinimide compounds which are not boronated and one or more boronated succinimide compounds. No restrictions are placed on the ratio of the boronated succinimide compound. In each of component (C-1) and component (C-2), the ratio of the boronated succinimide compound may be, but is not limited to, from 5 to 100 percent by weight, from 20 to 100 percent by weight, or from 50 to 100 percent by weight, based on the weight of each of component (C-1) and component (C-2).

[0052] The 1st succinimide compound (C-1) has a weight-average molecular weight of 4,000 to 7,000. The weight-average molecular weight may be from 5,000 to 7,000, or even from 5,200 to 6,800. If the molecular weight of the 1st succinimide compound is less than 4,000, the anti-shudder properties deteriorate. In the present disclosure, the weight-average molecular weight of the 1st succinimide compound is measured using an RI (differential refractometry) detector, with a solvent of THF (tetrahydrofuran), a packed column of styrene-divinylbenzene copolymer, a set temperature of 40° C., and a set flow rate of 1.0 mL/min, and is expressed in polystyrene-converted value.

[0053] When a boronated succinimide compound is used as the 1st succinimide compound, the boron content in component (C-1) may be, but is not limited to, from 0.1 to 3 percent by weight, from 0.2 to 2.5 percent by weight, from 0.2 to 2 percent by weight, or from 0.2 to 1.5 percent by weight, based on the weight of the boronated succinimide compound which is component (C-1). The nitrogen content in component (C-1) is, but not limited to, from 0.3 to 10 percent by weight, from 0.5 to 5 percent by weight, or from 0.8 to 2.5 percent by weight, based on the weight of the boronated succinimide compound which is component (C-1).

[0054] The content of the 1st succinimide compound in the lubricating oil composition is, but not limited to, from 0.05 to 2 percent by weight, from 0.08 to 1.8 percent by weight, or from 0.1 to 1.5 percent by weight, based on the total weight of the lubricating oil composition. If the content is less than the above lower limit, there is a possibility that sufficient washability may not be secured, and if it is more than the above upper limit, there is a possibility that sludge may be generated.

[0055] The 2nd succinimide compound (C-2) has a weight-average molecular weight of more than 7,000 not more than 10,000. The weight-average molecular weight is from 7,100 to 9,600 or from 7,500 to 9,200. If the molecular weight of the 2nd succinimide compound is more than 10,000, the low-temperature viscosity deteriorates.

[0056] In the present disclosure, the weight-average molecular weight of the 2nd succinimide compound is measured using an RI (differential refractometry) detector, with a solvent of THF (tetrahydrofuran), a packed column of styrene-divinylbenzene copolymer, a set temperature of 40° C., and a set flow rate of 1.0 mL/min, and is expressed in polystyrene-converted value.

[0057] When a boronated succinimide compound is used as the 2nd succinimide compound, the boron content in component (C-2) is, but not limited to, from 0.1 to 3 percent by weight, from 0.2 to 2.5 percent by weight, from 0.2 to 2 percent by weight, or from 0.2 to 1.5 percent by weight, based on the weight of the boronated succinimide compound

which is component (C-2). The nitrogen content in component (C-2) is, but not limited to, from 0.2 to 5 percent by weight, from 0.3 to 2.5 percent by weight, or from 0.5 to 2 percent by weight, based on the weight of the boronated succinimide compound which is component (C-2).

[0058] The content of the 2nd succinimide compound in the lubricating oil composition is, but not limited to, from 0.05 to 2 percent by weight, from 0.08 to 1.8 percent by weight, or from 0.1 to 1.5 percent by weight. If the content is less than the above lower limit, sufficient washability may not be secured, and if it is more than the above upper limit, low-temperature viscosity occurs.

[0059] The lubricating oil composition of the present disclosure may comprise other ashless dispersants in combination with above component (C-1) and above component (C-2). A typical example of the other ashless dispersant includes a succinamide compound.

(D) Phosphorus-Based Extreme Pressure Agent

[0060] The lubricating oil composition of the present disclosure comprises a phosphorus-based extreme pressure agent (D). The phosphorus-based extreme pressure agent means an extreme pressure agent containing phosphorus. The extreme pressure agent containing phosphorus that may be used as the phosphorus-based extreme pressure agent may not be particularly limited. The content of the phosphorus-based extreme pressure agent in the lubricating oil composition is, but not limited to, from 0.01 to 2.5 percent by weight, from 0.02 to 1.5 percent by weight, or from 0.02 to 1.0 percent by weight, based on the total weight of the lubricating oil composition. In the present disclosure, the phosphorus-based extreme pressure agent may contain sulfur. Phosphorus-sulfur-based extreme pressure agents such as thiophosphate are included in the phosphorus-based extreme pressure agent, and are not included in the sulfur-based extreme pressure agent mentioned hereinafter. However, in the present disclosure, the phosphorus-based extreme pressure agent does not include zinc dithiophosphate. In some embodiments, the phosphorus-based extreme pressure agent of the present disclosure does not contain a metal element.

[0061] The lubricating oil composition of the present disclosure may comprise a sulfur-based extreme pressure agent in addition to the above phosphorus-based extreme pressure agent. A sulfur-based extreme pressure agent means an extreme pressure agent containing sulfur. The extreme pressure agent containing sulfur that may be used as the sulfur-based extreme pressure agent may not be particularly limited. Furthermore, as described above, the lubricating oil composition of the present disclosure does not comprise zinc dithiophosphate. Therefore, the sulfur-based extreme pressure agent in the lubricating oil composition does not include zinc dithiophosphate. In some embodiments, the sulfur-based extreme pressure agent in the lubricating oil composition does not contain a metal element. The content of the sulfur-based extreme pressure agent in the lubricating oil composition of the present disclosure is not more than 0.1 percent by weight, not more than 0.08 percent by weight, or not more than 0.06 percent by weight, based on the lubricating oil composition. If the lubricating oil composition comprises the sulfur-based extreme pressure agent at a quantity of more than the above upper limit, the anti-shudder properties deteriorate.

[0062] As described above, the lubricating oil composition of the present disclosure does not comprise zinc dithiophosphate. The reason for it is that the presence of zinc dithiophosphate in the lubricating oil composition causes the anti-shudder properties of the lubricating oil composition to deteriorate.

[0063] Examples of the phosphorus-based extreme pressure agent include phosphate, acidic phosphate, phosphite, acidic phosphite, and amine salts thereof, phosphoric acid and phosphorous acid. One of these may be used alone, or two or more thereof may be used in combination. In some embodiments, the phosphorus-based extreme pressure agent is a combination of at least one selected from phosphate, acidic phosphate, phosphite, acidic phosphite, and amine salts thereof, and at least one selected from phosphoric acid and phosphorous acid. In addition to these phosphorus-based extreme pressure agents, a sulfur-based extreme pressure agent may also be contained, and its content should satisfy the conditions described above.

[0064] Phosphate and acidic phosphate are represented by $(R^2O)_aP(=O)(OH)_{3-a}$, wherein "a" is 0, 1, 2 or 3, R^2 is each independently a monovalent hydrocarbon group having 4 to 30 carbon atoms. When $a=1$ or 2, the compound is acidic phosphate.

[0065] Phosphite and acidic phosphite are represented by $(R^3O)_bP(=O)(OH)_{2-b}H$, wherein "b" is 0, 1 or 2, R^3 is each independently a monovalent hydrocarbon group having 4 to 30 carbon atoms.

[0066] The phosphate and acidic phosphate are, but not limited to, monoalkyl phosphate, dialkyl phosphate or trialkyl phosphate.

[0067] The phosphite and acidic phosphite are, but not limited to, monoalkyl phosphite and dialkyl phosphite.

[0068] The phosphorus-based extreme pressure agent also includes a compound obtained by substituting at least one oxygen atom of a phosphate, phosphite, acidic phosphate and acidic phosphite with a sulfur atom, such as thiophosphate, thiophosphite, acidic thiophosphate, and acidic thiophosphite.

[0069] More specific examples thereof include, but are not limited to, mono-octyl phosphate, dioctyl phosphate, trioctyl phosphate, mono-octyl phosphite, dioctyl phosphite, mono-octyl thiophosphate, dioctyl thiophosphate, trioctyl thiophosphate, mono-octyl thiophosphite, dioctyl thiophosphite, monododecyl phosphate, didodecyl phosphate, tridodecyl phosphate, monododecyl phosphite, didodecyl phosphite, acidic butyl phosphate, acidic hexyl phosphate, acidic octyl phosphate, acidic dodecyl phosphate, acidic butyl phosphite, acidic hexyl phosphite, acidic octyl phosphite, acidic dodecyl phosphite, etc.

[0070] In addition, alkylamine salts and alkenylamine salts of the partial esters among the above compounds may also be appropriately used. In other words, amine salts of acidic phosphates and amine salts of acidic phosphites may be used, but they are not limited to these compounds.

[0071] More specific examples thereof include amine salts of mono-octyl phosphate, amine salts of dioctyl phosphate, amine salts of trioctyl phosphate, amine salts of dioctyl phosphite, amine salts of trioctyl phosphite, amine salts of dioctyl thiophosphate, amine salts of trioctyl thiophosphate, amine salts of tridodecyl thiophosphate, amine salts of didodecyl phosphate, amine salts of didodecyl phosphite, amine salts of tridodecyl phosphite, amine salts of didodecyl phosphite, amine salts

of tridodecyl phosphite, amine salts of tridodecyl thiophosphate, amine salts of trihexadodecyl phosphate, amine salts of trihexadodecyl phosphite, amine salts of acidic butyl phosphite, amine salts of acidic hexyl phosphate, amine salts of acidic octyl phosphate, amine salts of acidic dodecyl phosphate, amine salts of acidic butyl phosphite, amine salts of acidic hexyl phosphite, amine salts of acidic octyl phosphite, amine salts of acidic dodecyl phosphite, etc.

[0072] Moreover, phosphoric acid and phosphorous acid may be suitably used as phosphorus-based extreme pressure agent other than the above phosphorus-based extreme pressure agents. Moreover, the phosphorus-based extreme pressure agent may include, but is not limited to, a combination of at least one selected from acidic phosphate, acidic phosphite, phosphate and phosphite and amine salts thereof, and at least one selected from phosphoric acid and phosphorous acid. When the combination is used, the ratio of phosphoric acid and phosphorous acid is, but not limited to, 0.02 to 0.5 percent by weight based on the total weight of the phosphorus-based extreme pressure agent.

[0073] In some embodiments, the phosphorous-based extreme pressure agent may include a combination of an acidic phosphate and at least one selected from phosphoric acid and phosphorous acid. In some embodiments, the acidic phosphate may be at least one selected from acidic butyl phosphate, acidic hexyl phosphate, acidic octyl phosphate and acidic dodecyl phosphate.

[0074] Examples of a sulfur-based extreme pressure agent include sulfurated olefins, sulfurated fats or oils, sulfurated esters and polysulfide.

[0075] Sulfurated olefins are compounds obtained by sulfurating olefins. Sulfurated olefins are obtained, for example, by sulfurating olefins such as polyisobutylenes and terpenes, using sulfur or another sulfurating agent.

[0076] Sulfurated fats or oils are reaction products of fats or oils and sulfur. For example, they can be obtained by sulfurating animal or vegetable fats or oils such as lard, suet, whale oil, palm oil, coconut oil and rapeseed oil. The product of the above reaction is not a single type of material but may be a mixture of several materials.

[0077] In addition to the above sulfurated fats or oils, sulfurated esters include those obtained by reacting an organic acid such as saturated fatty acids, unsaturated fatty acids, dicarboxylic acids, aromatic carboxylic acids, etc., with an alcohol to prepare an ester compound and sulfurating the ester compound using sulfur or another sulfurating agent.

[0078] The lubricating oil composition of the present disclosure may further comprise (E) a metallic detergent and/or (F) an ether sulfonate compound in addition to above components (A) to (D).

(E) Metallic Detergent

[0079] A metallic detergent includes a detergent containing an alkali metal or alkaline earth metal. Examples thereof include, but are not limited to, sulfonates containing an alkali metal or alkaline earth metal, salicylates containing an alkali metal or alkaline earth metal, and phenates containing an alkali metal or alkaline earth metal. Examples of an alkali metal or alkaline earth metal include, but are not limited to, magnesium, barium, sodium and calcium.

[0080] Examples of a sulfonate containing an alkali metal or alkaline earth metal include, but are not limited to, calcium phenate and magnesium phenate.

[0081] Examples of a salicylate containing an alkali metal or alkaline earth metal include, but not are limited to, calcium salicylates and magnesium salicylates.

[0082] Examples of a phenate containing an alkali metal or alkaline earth metal include, but not are limited to, calcium phenate and magnesium phenate.

[0083] The quantity of the alkali metal or alkaline earth metal in the metallic detergent is, but not limited to, from 0.1 to 20 percent by weight, from 0.5 to 15 percent by weight, or from 1.0 to 15 percent by weight.

[0084] The metallic detergent may have a total base number that is, but not limited to, from 10 to 500 mgKOH/g, from 50 to 400 mgKOH/g, from 150 to 400 mgKOH/g, from 200 to 400 mgKOH/g, from 300 to 400 mgKOH/g, or from 310 to 400 mgKOH/g. When the total base number is in the above range, the washability effect is high and sludge generation can be prevented.

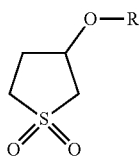
[0085] The metallic detergent may be contained in the lubricating oil composition at any ratio. For example, the lubricating oil composition comprises a content of from 0 to 5 percent by weight, from 0.1 to 2 percent by weight, or from 0.2 to 1 percent by weight of a metallic detergent.

[0086] A single metallic detergent may be used alone, or two or more thereof may be used in combination. When two or more metallic detergents are used in combination, examples of the combination include, but are not limited to, a combination of two or more sulfonate compounds, a combination of two or more salicylate compounds, a combination of two or more phenate compounds, a combination of one or more sulfonate compounds and a salicylate compound, a combination of a sulfonate compound and one or more phenate compounds, and a combination of one or more salicylates compounds and one or more phenate compounds.

(F) Ether Sulfolane Compound

[0087] By comprising an ether sulfolane compound, the lubricating oil composition of the present disclosure can secure moderate seal rubber swelling properties. The ether sulfolane compound is a compound represented by following formula:

[Chem. 5]



wherein R is an alkyl group having 1 to 20 carbon atoms, or an alkyl group having 8 to 16 carbon atoms.

[0088] The content of an ether sulfolane compound in the lubricating oil composition is from 0 to 5 percent by weight, from 0.1 to 2 percent by weight, or from 0.2 to 1 percent by weight.

[0089] The lubricating oil composition of the present disclosure may further comprise additives other than above components (B) to (F). Examples of the other additive include oiliness agents, anti-wear agents, extreme pressure agents other than phosphorus-based and sulfur-based extreme pressure agents, rust-preventive agents, friction modifiers, antioxidants, corrosion inhibitors, metal deacti-

vators, pour point depressants, antifoaming agents, coloring agents and package additives for automatic transmission fluid. Package additives for lubricating oil containing at least one of the above additives can be added.

[0090] The kinematic viscosity at 100° C. of the lubricating oil composition of the present disclosure is, but not limited to, from 3 to 10 mm²/s, from 3 to 8 mm²/s, from 4 to 7.5 mm²/s, or from 4 to 6 mm²/s. When the kinematic viscosity at 100° C. of the lubricating oil composition is less than the above lower limit, it may not be possible to secure the friction coefficient. When it is more than the above upper limit, the anti-shudder properties may deteriorate.

[0091] The viscosity index of the lubricating oil composition of the present disclosure is, but not limited to, not less than 150, or not less than 160. When the viscosity index of the lubricating oil composition is less than the above lower limit, it may not be possible to sufficiently secure the low-temperature behavior. The upper limit thereof is, but not limited to, 250.

[0092] In spite of its low viscosity, the lubricating oil composition of the present disclosure has not only a sufficiently high intermetallic friction coefficient but also anti-shudder properties. In addition, as described above, by specifying the constitutions of the base oil and the viscosity index improver in accordance with the present disclosure, the shear stability can also be secured. Furthermore, by comprising an ether sulfolane compound, it can secure moderate seal rubber swelling properties. In addition, by using a metallic detergent having a total base number of 200 to 400 mgKOH/g, it can secure washability while preventing sludge generation. The lubricating oil composition of the present disclosure can be suitably used for a non-stage transmission.

Examples

[0093] The lubricating oil compositions of the present disclosure will now be described in greater detail by means of examples and comparative examples, but the present disclosure is not limited to these examples.

[0094] The components used in the examples and comparative examples are as follows. Lubricating oil compositions were prepared by mixing the components shown below at the amounts shown in Table 1 or Table 2. Hereinafter, KV100 means a kinematic viscosity at 100° C., VI means a viscosity index, and PMA means polymethacrylate.

(A) Lubricant Base Oil

[0095] Mineral oil 1: highly hydrorefined paraffinic base oil (KV100=3.1 mm²/s, VI=112)

Mineral oil 2: highly hydrorefined paraffinic base oil (KV100=4.2 mm²/s, VI=122)

Mineral oil 3: highly hydrorefined paraffinic base oil (KV100=4.2 mm²/s, VI=134)

Mineral oil 4: hydrorefined paraffinic base oil (KV100=2.2 mm²/s, VI=109)

Mineral oil 5: hydrorefined paraffinic base oil (KV100=2.5 mm²/s, VI=99)

Synthetic base oil 1: poly- α -olefin (KV100=10 mm²/s, VI=137)

Synthetic base oil 2: poly- α -olefin (KV100=40 mm²/s, VI=147)

Synthetic base oil 3: ethylene- α -olefin copolymer (KV100=10 mm²/s, VI=150)

Synthetic base oil 4: ethylene- α -olefin copolymer
(KV100=40 mm²/s, VI=155)

TABLE 2-continued

		Example 8	Example 9	Example 10	Example 11	Example 12	Example 13	Example 14	Example 15
(E)	Calcium sulfonate	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
(D)	Phosphoric acid	0.04		0.04	0.04	0.04	0.19		
	Phosphorous acid		0.04						
	Acidic butyl phosphate	0.15	0.15					0.19	0.15
	Amine salt of acidic butyl phosphate			0.15					
	Acidic hexyl phosphate				0.15				
	Acidic butyl phosphite					0.15			
Sulfur-based extreme pressure agent	Sulfurated olefin								0.04
(F)	Ether sulfolane compound		0.60	0.60	0.60	0.60	0.60	0.60	0.60
	Other additives package	2.81	2.81	2.81	2.81	2.81	2.81	2.81	2.81
	[C2]/[C1]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5

TABLE 3

		Comp. Example 1	Comp. Example 2	Comp. Example 3	Comp. Example 4	Comp. Example 5
(A)	Mineral oil 1	70.39	70.39	70.39	70.39	Commercially available product
	Synthetic base oil 2	20.95	20.95	20.95	20.95	
(B)	PMA-based viscosity index improver	3.08	3.08	3.08	3.08	
(C-2)	Boron-containing succinimide compound 2 (Mw = 8500)		1.49	1.49	1.49	
(C-1)	Boron-containing succinimide compound 1 (Mw = 5600)	0.33	0.33	0.33	0.33	
(C-1)	Boron-containing succinimide compound 3 (Mw = 4600)	1.49				
(E)	Calcium sulfonate	0.16	0.16	0.16	0.16	
(D)	Phosphoric acid	0.04		0.04		
	Acidic butyl phosphate	0.15			0.15	
Sulfur-based extreme pressure agent	Sulfurated olefin		0.19	0.15		
Comparative extreme pressure agent	Zinc dithiophosphate				0.04	
(F)	Ether sulfolane compound	0.60	0.60	0.60	0.60	0.60
	Other additives package	2.81	2.81	2.81	2.81	2.81
	[C2]/[C1]	0	4.5	4.5	4.5	4.5

[0103] Various properties of each lubricating oil composition were measured using the following methods. The results are shown in Tables 4 to 6.

[0104] (1) Kinematic viscosity at 100° C. testing method: The measurements were conducted in accordance with ASTM D445.

[0105] (2) Viscosity index testing method: The measurements were conducted in accordance with ASTM D2270.

[0106] (3) Shear stability testing method: In accordance with JASO M347-2014, the viscosity after 10 hours at 100° C. was measured, and the rate of change from the viscosity before the beginning of testing was calculated.

[0107] (4) Shudder prevention lifespan testing method: In accordance with JASO M349-2012, the time periods in which each dp/dv (average in 1.0 to 2.0 m/s), evaluated at 40° C., 60° C., 80° C. and 120° C., fell below -2×10^{-3} were calculated.

[0108] (5) Friction coefficient (comparison with a commercially available product): Using an SRV friction wear

tester manufactured by Optimol, an SUJ ball having a diameter of 10 mm, and an SUJ disk having a diameter of 24 mm and a height of 6.9 mm, which is lapping processed, manufactured by the same company, testing was conducted with the load of 100 N, the temperature of 100° C., the frequency of 50 Hz, and the amplitude of 0.5 mm, the average value of the friction coefficient after 30 minutes was determined. The ratio of the friction coefficient of each lubricating oil composition to that of a commercially available oil (Comparative Example 5) was determined (the friction coefficient of the commercially available oil is 1.0).

[0109] (6) Rubber swelling testing method: In accordance with ASTM D471, a C-type dumbbell-shaped ACM rubber (T945, manufactured by NOK) was used, immersed in the oil sample at 150° C., and the volume change after 70 hours was determined.

[0110] In Comparative Example 5, a commercially available lubricating oil composition for transmission was evaluated.

TABLE 4

		Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7
Base oil Composition	KV100	4.0	4.0	4.0	3.7	4.0	4.0	3.0
	KV100	5.5	5.5	5.5	5.2	5.5	5.5	5.5
	VI	163	168	170	168	170	168	151
	Shear stability	4	4	4	4	4	4	4
	Shudder	450	450	450	450	450	450	450
	Coefficient of friction (Ratio relative to Comparative Example 5)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Swelling properties	5	5	5	5	5	5	5

TABLE 5

		Example 8	Example 9	Example 10	Example 11	Example 12	Example 13	Example 14	Example 15
Base oil Composition	KV100	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
	KV100	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	VI	163	163	163	163	163	163	163	163
	Shear stability	4	4	4	4	4	4	4	4
	Shudder	450	450	450	450	450	450	450	450
	Coefficient of friction (Ratio relative to Comparative Example 5)	1.00	0.98	0.96	0.95	0.95	1.04	0.95	0.95
	Swelling properties	1	5	5	5	5	5	5	5

TABLE 6

		Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Base oil Composition	KV100	3.7	4.0	4.0	4.0	
	KV100	5.2	5.5	5.5	5.5	7.2
	VI	161	163	163	163	201
	Shear stability	4	4	4	4	21
	Shudder	20	30	60	60	200
	Coefficient of friction (Ratio relative to Comparative Example 5)	1.00	1.02	1.01	1.01	1.0
	Swelling properties	5	5	5	5	6

[0111] As shown in Examples 1 to 15 described in Tables 4 and 5, the lubricating oil composition of the present disclosure comprises a combination of two types of succinimide compounds and a phosphorus-based extreme pressure agent, thereby it is capable of extending the shudder prevention lifespan without decreasing the intermetallic friction coefficient, although it has a low kinematic viscosity at 100° C. As shown in Comparative Example 1, if it does not comprise component (C-2), the anti-shudder properties deteriorate. If it comprises a sulfur-based extreme pressure agent at an amount of more than the upper limit specified by the present disclosure, the anti-shudder properties deteriorate.

[0112] As seen from the comparison of Example 1 with Example 8, when the constitution of component (A) is specified and the composition further comprises an ether sulfolane compound (F), the swelling property of the seal rubber can be further improved in addition to the above effects.

INDUSTRIAL APPLICABILITY

[0113] The lubricating oil composition of the present disclosure can be suitably used as a lubricating oil composition for an automobile transmission, especially for a non-stage transmission.

1. A lubricating oil composition comprising

- (A) a lubricant base oil,
- (C) (C-1) a succinimide compound or a boronated succinimide compound having a weight-average molecular weight of 4,000 to 7,000, and (C-2) a succinimide compound or a boronated succinimide compound having a weight-average molecular weight of more than 7,000 and not more than 10,000, and
- (D) a phosphorus-based extreme pressure agent,

wherein the lubricating oil composition does not comprise zinc dithiophosphate, and the lubricating oil composition may optionally comprise a sulfur-based extreme pressure agent, provided that a content of the sulfur-based extreme pressure agent is not more than 0.1 percent by weight based on the lubricating oil composition.

2. The lubricating oil composition according to claim 1, comprising, as a part or all of the component (A), 5 to 30 percent by weight, based on a total weight of the lubricating oil composition, of a poly- α -olefin or α -olefin copolymer having a kinematic viscosity at 100° C. of 6 to 80 mm²/s, and further comprising (B) a polymethacrylate having a weight-average molecular weight of 15,000 to 40,000.

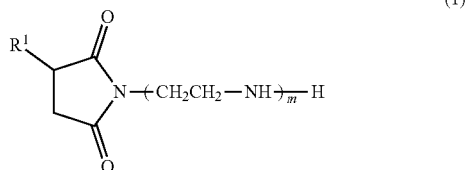
3. The lubricating oil composition according to claim 1, wherein a part or all of component (C-1) and component (C-2) is a boronated succinimide compound.

4. The lubricating oil composition according to claim 1, wherein a content of boron is 0.1 to 3 percent by weight based on the weight of the boronated succinimide compound in each of component (C-1) and component (C-2).

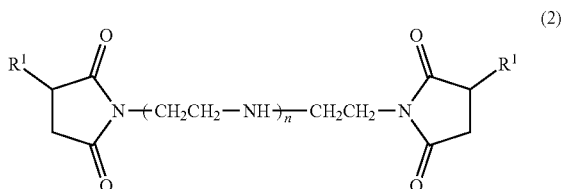
5. The lubricating oil composition according to claim 1, wherein a weight ratio of component (C-1) to component (C-2), i.e., (C-2)/(C-1), is 1 to 10.

6. The lubricating oil composition according to claim 1, wherein the succinimide compound is represented by following formula (1) or (2):

[Chem. 1]



[Chem. 2]



wherein R¹ is each independently an alkyl or alkenyl group having 40 to 400 carbon atoms, m is an integer of 1 to 20, and n is an integer of 0 to 20.

7. The lubricating oil composition according to claim 1, having a kinematic viscosity at 100° C. of 3 to 10 mm²/s.

8. The lubricating oil composition according to claim 1, having a viscosity index of 150 or higher.

9. The lubricating oil composition according to claim 1, wherein the phosphorus-based extreme pressure agent (D) is at least one selected from an acidic phosphate, acidic phosphite, phosphate, phosphite, and amine salts thereof, phosphoric acid, and phosphorus acid.

10. The lubricating oil composition according to claim 9, wherein the phosphorus-based extreme pressure agent (D) is at least one selected from an acidic phosphate, acidic phosphite, phosphate, phosphite and amine salts thereof, combined with at least one selected from phosphoric acid and phosphorus acid.

11. The lubricating oil composition according to claim 1, further comprising (E) a metallic detergent.

12. The lubricating oil composition according to claim 1, further comprising (F) an ether sulfolane compound.

13. The lubricating oil composition according to claim 1, which is for a non-stage transmission.

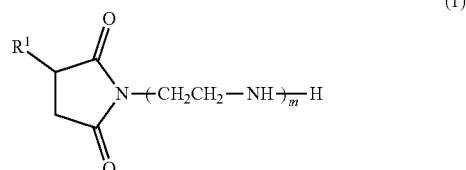
14. The lubricating oil composition according to claim 2, wherein a part or all of component (C-1) and component (C-2) is a boronated succinimide compound.

15. The lubricating oil composition according to claim 2, wherein a content of boron is 0.1 to 3 percent by weight based on the weight of the boronated succinimide compound in each of component (C-1) and component (C-2).

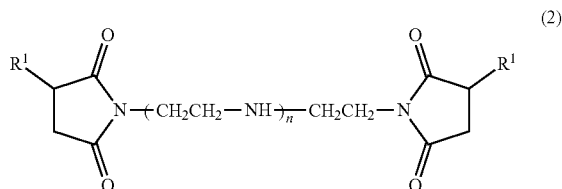
16. The lubricating oil composition according to claim 2, wherein a weight ratio of component (C-1) to component (C-2), i.e., (C-2)/(C-1), is 1 to 10.

17. The lubricating oil composition according to claim 2, wherein the succinimide compound is represented by following formula (1) or (2):

[Chem. 1]



[Chem. 2]



wherein R¹ is each independently an alkyl or alkenyl group having 40 to 400 carbon atoms, m is an integer of 1 to 20, and n is an integer of 0 to 20.

18. The lubricating oil composition according to claim 2, having a kinematic viscosity at 100° C. of 3 to 10 mm²/s.

19. The lubricating oil composition according to claim 2, having a viscosity index of 150 or higher.

20. The lubricating oil composition according to claim 2, wherein the phosphorus-based extreme pressure agent (D) is at least one selected from an acidic phosphate, acidic phosphite, phosphate, phosphite, and amine salts thereof, phosphoric acid, and phosphorus acid.

* * * * *