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(54) LUBRICANT OIL COMPOSITION FOR ROTARY COMPRESSOR

(57) A lubricating oil composition for a rotary compressor capable of imparting high extreme pressure property while maintaining high oxidation stability is provided by mixing, in (a) a base oil, (b) an antioxidant and (c) a dithiophosphate ester compound represented by the formula (I) in an amount of 0.05% by mass or more and less than 2.0% by mass based on the total composition.

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Description

Technical Field

[0001] The present invention relates to a lubricating oil composition for a rotary compressor. In particular, the present invention relates to a lubricating oil composition for a rotary compressor, in which the lubricating oil composition is capable of imparting high extreme pressure property while maintaining high oxidation stability.

Background Art

[0002] In the field of an equipment oil, such as a compressor oil, a turbine oil and a hydraulic oil, particularly in a compressor oil for a gear-driven compressor and the like, excellent oxidation stability and extreme pressure property have been demanded, but it has been difficult to achieve both of them simultaneously. Specifically, it has been known that an acidic phosphate ester amine salt and a sulfur-phosphorus (SP) extreme pressure additive, which have been used since they are generally said to have excellent oxidation stability, are generally insufficient in extreme pressure property, whereas a zinc dialkyldithiophosphate (ZnDTP), which has been said to have excellent extreme pressure property, significantly impairs the oxidation stability of the oil.

[0003] As a compound that enhances extreme pressure property, for example, PTL 1 describes the use of the particular dithiophosphate ester in an amount of 2.0% by mass or more and 8.0% by mass or less for improving antiwear property of an engine oil. PTL 2 describes the use of a combination of the specific monothiophosphate ester and the specific dithiophosphate ester in a hydraulic oil for suppressing an undesirable hydrolysate from being formed.

Citation List

Patent Literatures

[0004]

PTL 1: WO 02/102945
PTL 2: JP-A-2005-139451

Summary of Invention

Technical Problem

[0005] However, the technique described in PTL 1 is for solving the problem in an engine oil, but does not relate to the achievement of both oxidation stability and extreme pressure property in a lubricating oil for a compressor, particularly a lubricating oil for a rotary compressor. The technique described in PTL 2 is for solving the problem in a hydraulic oil, but does not relate to the achievement of both oxidation stability and extreme pressure property in a lubricating oil for a compressor, particularly a lubricating oil for a rotary compressor.

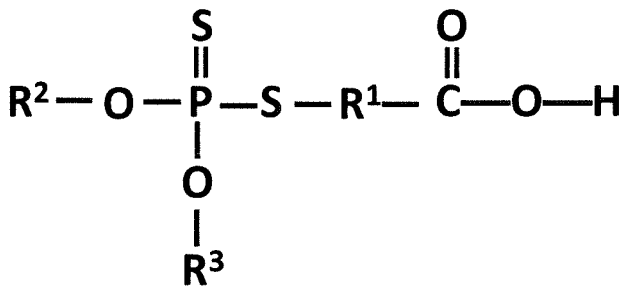
[0006] Accordingly, an object of the present invention is to provide a lubricating oil composition for a rotary compressor, in which the lubricating oil composition is capable of imparting high extreme pressure property while maintaining high oxidation stability.

[0007] Another object of the present invention is to provide the aforementioned lubricating oil composition for a rotary compressor, which is capable of suppressing the formation of sludge as well as achieving both the excellent oxidation stability and extreme pressure property.

Solution to Problem

[0008] The present invention relates to the following aspects.

(1) A lubricating oil composition for a rotary compressor, containing (a) a base oil, (b) an antioxidant, and (c) a dithiophosphate ester compound represented by the following formula (I) in an amount of 0.05% by mass or more and less than 2.0% by mass based on the total amount of the composition:



(I)

wherein R^1 represents a linear or branched alkylene group having from 1 to 8 carbon atoms; and R^2 and R^3 each represent a hydrocarbon group having from 3 to 20 carbon atoms.

(2) The lubricating oil composition for a rotary compressor according to the item (1), wherein the lubricating oil composition contains (c) the dithiophosphate ester compound represented by the following formula (I) in an amount of more than 0.1% by mass and less than 2% by mass.

(3) The lubricating oil composition for a rotary compressor according to the item (1) or (2), wherein R^1 represents a linear or branched alkylene group having from 1 to 8 carbon atoms; and R^2 and R^3 each represent a linear or branched alkylene group having from 3 to 20 carbon atoms.

(4) The lubricating oil composition for a rotary compressor according to any one of the items (1) to (3), wherein the antioxidant is at least one kind selected from a phosphorus compound, a phenol compound, a phenylamine compound, and a napthylamine compound.

(5) The lubricating oil composition for a rotary compressor according to any one of the items (1) to (4), wherein the lubricating oil composition contains the antioxidant in an amount of 0.01% by mass or more and 10% by mass or less.

(6) The lubricating oil composition for a rotary compressor according to any one of the items (1) to (5), wherein the base oil is a mineral oil.

(7) The lubricating oil composition for a rotary compressor according to any one of the items (1) to (6), wherein the rotary compressor is a gear-driven rotary compressor.

(8) The lubricating oil composition for a rotary compressor according to any one of the items (1) to (7), wherein the rotary compressor is a screw compressor, a movable vane compressor, a scroll compressor, or a tooth compressor.

Advantageous Effects of Invention

[0009] According to the present invention, with respect to a lubricating oil composition for a rotary compressor, provided is a lubricating oil composition capable of imparting high extreme pressure property while maintaining high oxidation stability.

[0010] According to the present invention, furthermore, with respect to the aforementioned lubricating oil composition for a rotary compressor, provided is a lubricating oil composition for a rotary compressor which is capable of suppressing the formation of sludge as well as achieving both the excellent oxidation stability and extreme pressure property.

Description of Embodiments

[0011] The present invention will be described in more detail below.

[0012] A lubricating oil composition for a compressor generally contains an antioxidant since the lubricating oil composition is demanded to have high oxidation stability in view of the usage pattern and the usage cycle thereof. In addition, a lubricating oil composition for a compressor, particularly a lubricating oil composition for a rotary compressor, such as a gear-driven compressor, is also demanded to have high extreme pressure property, but an SP extreme pressure additive having been used conventionally in a lubricating oil impairs the oxidation stability of the oil in the long-term use thereof.

[0013] Under the circumstances, the present inventor has found that the use of the specific amount of the dithiophosphate ester compound having the particular structure having a COOH group in a lubricating oil for a rotary compressor imparts excellent extreme pressure property without impairing the oxidation stability thereof for a prolonged period of time, and suppresses the formation of sludge to a level that causes no practical problem. Such a dithiophosphate ester compound having a COOH group has been generally considered to impair the oxidation stability, and thus the above finding is unexpected. The present invention has been completed based on these grounds.

[0014] The technique described in PTL 1 is for addressing the problem relating to an engine oil, which is assumed to be replaced in a shorter period of time than a compressor oil. Accordingly, the demanded capability for suppressing sludge is low, the long-term oxidation stability of the lubricating oil for a compressor is not focused, and also there is no

attention to the simultaneous achievement of the oxidation stability and the extreme pressure property. The technique described in PTL 2 is for addressing the problem relating to a hydraulic oil, which is assumed to be replaced in a shorter period of time than a compressor oil. Accordingly, the demanded capability for suppressing sludge is low, there is no attention to the simultaneous achievement of the oxidation stability and the extreme pressure property of a compressor oil, particularly a lubricating oil for a rotary compressor, for a prolonged period of time, which is realized in the present invention by the use of the dithiophosphate ester compound, and thus the problems and the constitutions thereof do not describe the present invention.

[0015] The lubricating oil composition for a rotary compressor (which may be hereinafter referred simply to as a lubricating oil composition) of the present invention contains (a) a base oil, (b) an antioxidant, and (c) a dithiophosphate ester compound represented by the above formula (I) in an amount of 0.05% by mass or more and less than 2.0% by mass based on the total amount of the composition.

(a) Base Oil

[0016] The base oil used in the lubricating oil composition for a rotary compressor of the present invention may be any of a mineral oil and a synthetic oil. The kinds and the like of the mineral oil and the synthetic oil are not particularly limited, and examples of the mineral oil include a paraffin base mineral oil, an intermediate base mineral oil and a naphthene base mineral oil, which are obtained by an ordinary refining method, such as solvent refining and hydrogenation refining.

[0017] Examples of the synthetic oil include polybutene, polyolefin (α-olefin (co)polymer), various esters (such as a polyol ester, a dibasic acid ester and a phosphate ester), various ethers (such as polyphenyl ether), and isomerized products of slack wax and GTL wax.

[0018] The mineral oil and the synthetic oil may be used solely or as a mixture of two or more kinds of base oils selected from the above which may be mixed in an arbitrary ratio.

[0019] The viscosity of the base oil used in the lubricating oil composition of the present invention may be arbitrary, and in consideration of the lubricating property, the cooling property, and the frictional loss on agitation, the kinetic viscosity at 40°C thereof may be 1 mm^2/s or more and 10,000 mm^2/s or less, preferably 5 mm^2/s or more and 500 mm^2/s or less, and more preferably 10 mm^2/s or more and 100 mm^2/s or less. In the case where two or more kinds of base oils are used, the kinetic viscosity of the mixed base oil is preferably in the aforementioned range.

[0020] In the present invention, the base oil used is preferably a mineral oil from the standpoint of the cost and the supply stability.

(b) Antioxidant

[0021] As the antioxidant of the component (b), any one that is generally used in a lubricating oil may be used, examples of which include an amine compound, a phosphorus compound, a sulfur compound, a phosphorus-sulfur-containing compound, and a phenol compound.

[0022] Examples of the amine compound include a phenylamine compound, such as a monoalkyldiphenylamine compound, e.g., monooctyldiphenylamine and monononyldiphenylamine; a dialkyldiphenylamine compound, e.g., 4,4'-dibutyldiphenylamine, 4,4'-dipentyldiphenylamine, 4,4'-dihexyldiphenylamine, 4,4'-diheptyldiphenylamine, 4,4-dioctyldiphenylamine and 4,4'-dinonyldiphenylamine; and a polyalkyldiphenylamine compound, e.g., tetrabutyldiphenylamine, tetrahexyldiphenylamine, tetraoctyldiphenylamine and tetranonyldiphenylamine; and a naphthylamine compound, such as α-naphthylamine, phenyl-α-naphthylamine, butylphenyl-α-naphthylamine, pentylphenyl-α-naphthylamine, hexylphenyl-α-naphthylamine, heptylphenyl-α-naphthylamine, octylphenyl-α-naphthylamine, nonylphenyl-α-naphthylamine, decylphenyl-α-naphthylamine and dodecylphenyl-α-naphthylamine.

[0023] Examples of the phosphorus compound, the sulfur compound and the phosphorus-sulfur-containing compound include a phosphorus compound, such as diethyl ((3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl)methyl)phosphonat e and diethyl 3,5-di-tert-butyl-4-hydroxybenzylphosphonate, a zinc dialkyldithiophosphate compound, such as zinc di-2-ethylhexyldithiophosphate, 2,6-di-tert-butyl-4-(4,6-bis(octylthio)-1,3,5-triazin-2-ylamin o)phenol, a thioterpene compound, such as a reaction product of phosphorus pentasulfide and pinene, and a dialkyl thiodipropionate, such as dilauryl thiodipropionate and distearyl thiodipropionate.

[0024] Examples of the phenol compound include a monocyclic phenol compound, such as 2,6-di-tert-butyl-4-methylphenol, 2,6-di-tert-butyl-4-ethylphenol, 2,4,6-tri-tert-butylphenol, 2,6-di-tert-butyl-4-hydroxymethylphenol, 2,6-di-tert-butylphenol, 2,4-dimethyl-6-tert-butylphenol, 2,6-di-tert-butyl-4-(N,N-dimethylaminomethyl)phenol, 2,6-di-tert-amyl-4-methylphenol and n-octadecyl 3-(4-hydroxy-3,5-di-tert-butylphenyl)propionate; and a polycyclic phenol compound, such as 4,4'-methylenebis(2,6-di-tert-butylphenol), 4,4'-isopropylidenebis(2,6-di-tert-butylphenol), 2,2'-methylenebis(4-methyl-6-tert-butylphenol), 4,4'-bis(2,6-di-tert-butylphenol), 4,4'-bis(2-methyl-6-tert-butylphenol), 2,2'-methylenebis(4-ethyl-6-tert-butylphenol), 4,4'-butylidenebis(3-methyl-6-tert-butylphenol), 2,2'-thiobis(4-methyl-6-tert-butylphenol) and

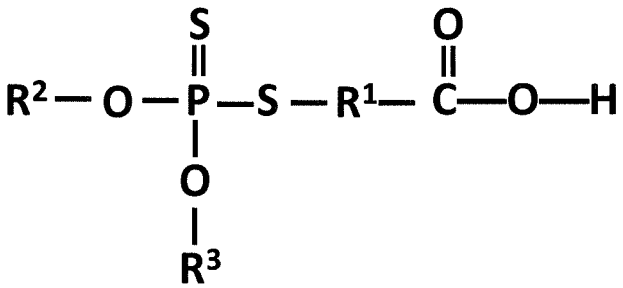
4,4'-thiobis(3-methyl-6-tert-butylphenol).

[0025] In these antioxidants, a phosphorus compound, a phenol compound and an amine compound are preferred, a phosphorus compound, a phenylamine compound and a naphthylamine compound are more preferred, and specifically 4,4'-dioctyldiphenylamine, octylphenyl-α-naphthylamine, diethyl 3,5-di-tert-butyl-4-hydroxybenzylphosphonate and the like are preferred, from the standpoint of the antioxidant capability.

[0026] The content of the antioxidant is generally approximately 0.01% by mass or more and approximately 10% by mass or less based on the total lubricating oil composition, and is preferably 0.03% by mass or more and 5% by mass or less, more preferably 0.1% by mass or more and 4% by mass or less, and further preferably 0.5% by mass or more and 3% by mass or less, based on the total lubricating oil composition, from the standpoint of the antioxidant capability for the lower limit and the solubility in the base oil for the upper limit.

(c) Dithiophosphate Ester Compound represented by Formula (I)

[0027] In the present invention, the dithiophosphate ester compound represented by the following formula (I) is used, and in the formula (I), R^1 represents a linear or branched alkylene group having from 1 to 8 carbon atoms; and R^2 and R^3 each represent a hydrocarbon group having from 3 to 20 carbon atoms.



(I)

[0028] In the case where R^1 in the formula (I) has more than 8 carbon atoms, the compound is liable to cause dissolution failure in the base oil. In view of this point, R^1 necessarily represents a linear or branched alkylene group having from 1 to 8 carbon atoms, preferably a linear or branched alkylene group having from 2 to 4 carbon atoms, and more preferably a branched alkylene group. Preferred specific examples thereof include $-CH_2CH_2-$, $-CH_2CH(CH_3)-$, $-CH_2CH(CH_2CH_3)-$ and $-CH_2CH(CH_2CH_2CH_3)-$, and more preferred examples thereof include $-CH_2CH(CH_3)-$ and $-CH_2CH(CH_2CH_3)-$.

[0029] In the case where R^2 and R^3 each have less than 3 carbon atoms, the compound is liable to cause adsorption failure to a metal surface due to the small molecular weight thereof, and in the case where they each have more than 20 carbon atoms, the compound is liable to cause dissolution failure in the base oil. In view of this point, R^2 and R^3 each preferably represent a linear or branched alkyl group having from 3 to 8 carbon atoms, and more preferably a linear or branched alkyl group having from 4 to 6 carbon atoms. Specifically, R^2 and R^3 each are preferably selected from the group consisting of propyl, isopropyl, butyl, isobutyl, t-butyl, pentyl, isopentyl, hexyl, 2-ethylbutyl, 1-methylpenthyl, 1,3-dimethylbutyl and 2-ethylhexyl groups, and among these, isobutyl and t-butyl are more preferred.

[0030] The dithiophosphate ester compound represented by the formula (I) is contained in an amount of 0.05% by mass or more and less than 2.0% by mass based on the total lubricating oil composition. When the content of the dithiophosphate ester compound is less than 0.05% based on the total lubricating oil composition, the extreme pressure property and the oxidation stability are deteriorated, and when the content thereof is 2.0% by mass or more, the oxidation stability is disadvantageously insufficient. In view of this point, the dithiophosphate ester compound is preferably contained in an amount of 0.07% by mass or more and less than 2.0% by mass, more preferably more than 0 .1% by mass and less than 2.0% by mass, further preferably 0.2% by mass or more and 1.0% by mass or less, and particularly preferably 0.2% by mass or more and 0.5% by mass or less, based on the total lubricating oil composition.

Other Lubricating oil Additives

[0031] The lubricating oil composition for a rotary compressor of the present invention contains (a) the base oil, (b) the antioxidant, and (c) the dithiophosphate ester compound represented by the formula (I) in an amount of 0.05% by mass or more and less than 2.0% by mass based on the total composition, and may further contain, as a lubricating oil additive depending on necessity, at least one kind selected from an additional extreme pressure additive, a defoaming agent, a rust inhibitor, an oiliness improver, a detergent-dispersant, a metal deactivator, a demulsifier, and the like, which are generally used in a lubricating oil.

[0032] Examples of the additional extreme pressure additive used include other compounds than the dithiophosphate

ester compound represented by the formula (I), for example, a sulfur extreme pressure additive, a phosphorus extreme pressure additive, and an SP extreme pressure additive, such as a dithiophosphate ester compound containing no COOH group and a monothiophosphate ester compound.

[0033] Examples of the sulfur extreme pressure additive include a dialkyl sulfide, dibenzyl sulfide, a dialkyl polysulfide, an alkylmercaptane, dibenzothiophene, dibutyl dithioglycolate, and 2,2'-dithiobis(benzothiazole), and the phosphorus extreme pressure additive is preferably a phosphate ester compound, a phosphite ester compound, an acidic phosphate ester compound, an acidic phosphite ester compound, and amine salts of these compounds, examples of which include a trialkyl phosphate, a triaryl phosphate, a trialkyl phosphonate, a trialkyl phosphite, triaryl phosphite and a dialkyl hydrogenphosphite.

[0034] Examples of the dithiophosphate ester compound containing no COOH group include compounds obtained by replacing H of the COOH group in the dithiophosphate ester compound represented by the formula (I) by an alkyl group having from 1 to 4 carbon atoms or the like, and examples of the monothiophosphate ester compound include a trialkyl trithiophosphate, a triaryl trithiophosphate and a triaralkyl trithiophosphate.

[0035] These extreme pressure additives may be used solely or as a combination thereof in such a range that the effects of the present invention are not impaired, and specifically may be used in an amount of 0.2 part by mass or less per 100 parts by mass of the lubricating oil composition.

[0036] The defoaming agent used may be a silicone defoaming agent, and a polymer silicone defoaming agent is preferred, examples of which include an organopolysiloxane, with a fluorine-containing organopolysiloxane, such as trifluoropropylmethylsilicone oil being preferred. The silicone defoaming agent is preferably contained in an amount of approximately 0.0005% by mass or more and approximately 0.5% by mass or less based on the total lubricating oil composition from the standpoint of the balance between the defoaming effect and the economic efficiency.

[0037] Examples of the rust inhibitor include a metal sulfonate, an aliphatic amine compound, an organic phosphite ester, an organic phosphate ester, an organic metal sulfonate salt, an organic metal phosphate salt, an alkenyl succinate ester and a polyhydric alcohol ester. The content of the rust inhibitor is generally approximately 0.01% by mass or more and approximately 10% by mass or less, and preferably 0.05% by mass or more and 5% by mass or less, based on the total lubricating oil composition, from the standpoint of the effect thereof added.

[0038] Examples of the oiliness improver include an aliphatic alcohol, a fatty acid compound, such as a fatty acid and a fatty acid metal salt, an ester compound, such as a polyol ester, a sorbitan ester and a glyceride, and an amine compound, such as an aliphatic amine. The content of the oiliness improver is generally approximately 0.1% by mass or more and approximately 30% by mass or less, and preferably 0.5% by mass or more and 10% by mass or less, based on the total lubricating oil composition, from the standpoint of the effect thereof added.

[0039] Examples of the detergent-dispersant include a metal sulfonate, a metal salicylate, a metal phenate, an aliphatic amine compound, an organic phosphite ester, an organic phosphate ester, an organic metal sulfonate salt, an organic metal phosphate salt, an alkenyl succinate ester and a polyhydric alcohol ester. The content of the detergent-dispersant is generally approximately 0.01% by mass or more and approximately 30% by mass or less, and preferably 0.05% by mass or more and 10% by mass or less, based on the total lubricating oil composition, from the standpoint of the effect thereof added.

[0040] Examples of the metal deactivator include a benzotriazole compound and a thiadiazole compound. The content of the metal deactivator is generally approximately 0.01% by mass or more and approximately 10% by mass or less, and preferably 0.01% by mass or more and 1% by mass or less, based on the total lubricating oil composition, from the standpoint of the effect thereof added.

[0041] Examples of a pour point depressant used include a polymethacrylate having a weight average molecular weight of approximately 50,000 or more and approximately 150,000 or less. The content of the pour point depressant is generally approximately 0.01% by mass or more and approximately 5% by mass or less, and preferably 0.02% by mass or more and 2% by mass or less, based on the total lubricating oil composition, from the standpoint of the effect thereof added, the other properties and the like.

[0042] Examples of the demulsifier include the known compounds, for example, an anionic surfactant, such as a sulfate ester salt of castor oil and a petroleum sulfonate salt, a cationic surfactant, such as a quaternary ammonium salt and an imidazoline surfactant, and a condensation product of ethylene oxide or propylene oxide having a molecular weight of approximately 1,500 or more and approximately 10,000 or less, specific examples of which include a polyoxyalkylene polyglycol and a dicarboxylate ester thereof, and an alkylene oxide adduct of an alkylphenol-formaldehyde polycondensate. The content of the demulsifier is generally approximately 0.01% by mass or more and approximately 5% by mass or less, and preferably 0.02% by mass or more and 2% by mass or less, based on the total lubricating oil composition.

[0043] The lubricating oil composition of the present invention preferably has a kinetic viscosity at 100°C (according to JIS K2283) of 7.5 mm^2/s or less, and more preferably 4.5 mm^2/s or more and 7.0 mm^2/s or less, from the standpoint of the enhancement of the energy saving property due to the reduction of friction.

[0044] The lubricating oil composition of the present invention preferably has a kinetic viscosity at 40°C of 55 mm^2/s or less, and more preferably 30 mm^2/s or more and 50 mm^2/s or less, from the standpoint of the enhancement of the

energy saving property due to the reduction of friction.

[0045] The lubricating oil composition of the present invention preferably has an acid value (according to JIS K2501) of 0 mgKOH/g or more and 1.0 mgKOH/g or less, and more preferably 0 mgKOH/g or more and 0.5 mgKOH/g or less, from the standpoint of the long-term storage stability.

[0046] The present invention also provides a method for lubricating a rotary compressor with the lubricating oil composition.

[0047] Specifically, the lubricating oil composition of the present invention may be charged as a lubricating oil to a rotary compressor, and thereby excellent extreme pressure property may be obtained while maintaining high oxidation stability. Furthermore, the formation of sludge is capable of being suppressed, in addition to the achievement of both the excellent oxidation stability and extreme pressure property.

[0048] Examples of the rotary compressor, to which the lubricating oil composition of the present invention is capable of being applied, include a screw compressor, a movable vane compressor, a scroll compressor, and a tooth compressor, and the present invention is applied particularly preferably to a gear-driven rotary compressor, in which extreme pressure property is demanded.

Example

[0049] The present invention will be described more specifically with reference to examples below, but the present invention is not limited to the examples.

Properties of Lubricating oil Composition

[0050] The properties of the lubricating oil composition were measured in the following manners.

(1) kinetic viscosity (40°C): according to JIS K2283
(2) acid value (indicator method): according to JIS K2501
(3) copper strip corrosion (100°C, 3 hours) : according to JIS K2513
(4) sulfur content (ppm): according to JIS K2541
(5) nitrogen content (ppm): according to JIS K2609
(6) phosphorus content (ppm): ICP analysis
(7) zinc content (ppm): ICP analysis

Evaluation Items and Evaluation Methods

(1) Load Bearing Test (Shell EP Test)

[0051] The test was performed according to ASTM D2783 with a four-ball tester under conditions of a rotation number of 1,800 rpm and an oil temperature of from 18.3 to 35.0°C. The load wear index (LWI) was obtained from the last non-seizure load *(LNL)* and the weld load (WL). A larger value therefor means better load bearing property.

(2) Wear Resistance Test (Shell Wear Test)

[0052] The test was performed according to ASTM D2783 with a four-ball tester under conditions of a load of 392 N, a rotation number of 1,200 rpm, an oil temperature of 75°C and a test time of 60 minutes. The average wear track diameter was calculated by averaging the wear track diameters caused by three 1/2-inch balls.

(3) Rotating Pressure Vessel Oxidation Test (RPVOT)

[0053] The test was performed according to JIS K2514 in the following manner. A container containing 5 g of the test oil, 5 mL distilled water, and a Cu coil as a catalyst was placed in a rotating pressure vessel, and oxygen was charged in the pressure vessel under pressure to 620 kPa. The pressure vessel was then rotated in a thermostat chamber at 150°C at 100 rpm while maintaining the pressure vessel at an angle of 30°, and the period of time (minute) from the time when the oxygen pressure was maximum to the time when the oxygen pressure was lowered to 175 kPa.

(4) Oxidation Stability Test (Modified IOT (Modified Indiana Oxidation Stability Test))

[0054] 300 mL of the test oil was placed in a glass tube, and a blowing tube having an outer diameter of 7.0 mm having diffuser stone attached to the end thereof and a Cu-Fe coil as a catalyst wound thereon was inserted to the glass tube

to make the Cu-Fe coil immersed in the oil. While controlling the oil temperature to 130°C, oxygen was blown from the blowing tube at 3 L/hr for from 240 to 960 hours, and the test oil was sampled in appropriate timing within the period and evaluated for the oxidation stability.

(5) FZG Gear Test

[0055] A test oil was evaluated for extreme pressure property according to DIN 51354 in such a manner that a torsional load was applied to a spur gear pair, and the load was increased until a damage was observed on the tooth surface. The wear amount of the spur gear pair was measured in each steps of load applied thereto, and the step where the wear amount was larger by 10 mg or more than the average slope of the wear curve was designated as the marginal load. The test conditions were as follows.
pinion rotation number: 2,250 rpm
oil temperature: 90°C at the start of operation (90°C or more thereafter)
oil amount: 1.25 L in gear box
pitch circumferential velocity of test gear: 8.30 m/s
load: load steps of 1 to 12
surface pressure: 15.7 to 198.9 kg/mm^2
test time: 15 minutes in each step
oil feeding method: oil bath

(6) Millipore Filter Test

[0056] According to SAE-ARP-785-63, the deposit formed in the test oil sampled during the oxidation stability test (modified IOT) was collected by filtration and measured for the weight thereof.

Examples 1 to 5 and Comparative Examples 1 to 6

[0057] The base oils shown in Tables 1 and 2 were prepared, to which the various additives shown in the tables were added to prepare lubricating oil compositions A to K (the numerals in the tables were in terms of percent by mass), and the resulting lubricating oil compositions each were evaluated for the aforementioned lubricating capabilities. The results are shown in Tables 3 and 4. The lubricating oil composition J of Comparative Example 5 was a commercially available product (Roto Inject Fluid) containing 0.54% by mass of ZnDTP as an extreme pressure additive.

Table 1

	Example 1	Example 2	Example 3	Example 4	Example 5
Lubricating oil composition	A	B	C	D	E
Paraffin mineral oil 1	66.70	66.70	66.83	66.78	66.87
Paraffin mineral oil 2	29.87	29.87	29.94	29.94	30.00
Antioxidant 1	2.00	2.00	2.00	2.00	2.00
Antioxidant 2	0.50	0.50	0.50	0.50	0.50
Antioxidant 3	0.20	0.20	0.20	0.20	0.20
Pour point depressant	0.05	0.05	0.05	0.05	0.05
Detergent-dispersant	0.08	0.08	0.08	0.08	0.08
Rust inhibitor	0.05	0.05	0.05	0.05	0.05
Metal deactivator	0.05	0.05	0.05	0.05	0.05
Defoaming agent	0.10	0.10	0.10	0.10	0.10

(continued)

		Example 1	Example 2	Example 3	Example 4	Example 5
Extreme pressure additive	Extreme pressure additive 1	0.20	0.20	0.20	0.20	0.10
	Extreme pressure additive 2	-	-	-	0.05	-
	Extreme pressure additive 3	0.20	-	-	-	-
	Extreme pressure additive 4	-	0.20	-	-	-
Total		100.00	100.00	100.00	100.00	100.00

Table 2

		Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Lubricating oil composition		F	G	H	I	J	K
Paraffin mineral oil 1		66.93	66.80	66.91	66.78	Commercially available product	66.97
Paraffin mineral oil 2		30.00	29.92	29.98	29.94		30.00
Antioxidant 1		2.00	2.00	2.00	2.00		2.00
Antioxidant 2		0.50	0.50	0.50	0.50		0.50
Antioxidant 3		0.20	0.20	0.20	0.20		0.20
Pour point depressant		0.05	0.05	0.05	0.05		0.05
Detergent-dispersant		0.08	0.08	0.08	0.08		0.08
Rust inhibitor		0.05	0.05	0.05	0.05		0.05
Metal deactivator		0.05	0.05	0.05	0.05		0.05
Defoaming agent		0.10	0.10	0.10	0.10		0.10
Extreme pressure additive	Extreme pressure additive 1	-	-	-	-		-
	Extreme pressure additive 2	-	0.05	-	-		-
	Extreme pressure additive 3	-	-	-	0.05		-
	Extreme pressure additive 4	-	-	0.04	-		-
	Extreme pressure additive 5	-	0.20	-	0.20		-

(continued)

		Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
	Extreme pressure additive 6	0.04	-	0.04	-		-
Total		99.96	99.80	99.96	99.80	100.00	100.00

Table 3

		Example 1	Example 2	Example 3	Example 4	Example 5
Shell four-ball EP test	LNL (N)	981	981	981	981	981
	WL (N)	1,569	1,569	1,569	1,569	1,569
	LWI (N)	389	393	390	389	390
Shell wear test	Average wear track diameter (mm)	0.45	0.47	0.46	0.45	0.46

Table 4

		Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6
Shell four-ball EP test	LNL (N)	235	490	392	618	981	490
	WL (N)	1,569	1,569	1,569	1,569	1,961	1,569
	LWI (N)	129	216	181	261	405	214
Shell wear test	Average wear track diameter (mm)	0.61	0.78	0.65	0.83	0.51	0.62

[0058] The base oils and the additives used were as follows.

Base Oil
Paraffin mineral oil 1

kinetic viscosity: 30.6 mm^2/s (40°C), 5.285 mm^2/s (100°C)
viscosity index: 104
acid value: 0.01 mgKOH/g
density: 0.863 (15°C)
flash point: 222°C
pour point: -17.5°C

Paraffin mineral oil 2

kinetic viscosity: 90.5 mm^2/s (40°C), 10.89 mm^2/s (100°C)
viscosity index: 107
acid value: 0.01 mgKOH/g
density: 0.869 (15°C)
flash point: 266°C
pour point: -17.5°C

Additives

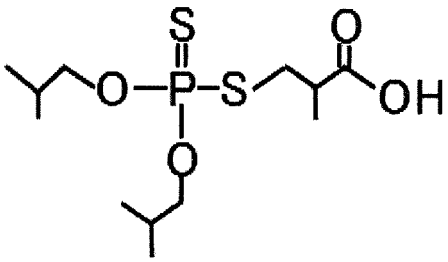
[0059]

Antioxidant 1: 4,4'-dioctyldiphenylamine
Antioxidant 2: p-t-octylphenyl-1-naphthylamine
Antioxidant 3: diethyl 3,5-di-tert-butyl-4-hydroxybenzylphosphonate

Extreme pressure additive 1:

[0060] dithiophosphate ester containing an end COOH group shown by the following structure (compound represented by the formula (I), wherein R^1 represents a propylene group, and R^2 and R^3 each represent an isobutyl group)

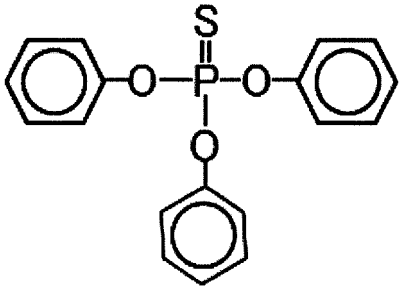
[Chem. 3]



Extreme pressure additive 2:

[0061] triphenylthiophosphate ester shown by the following structure

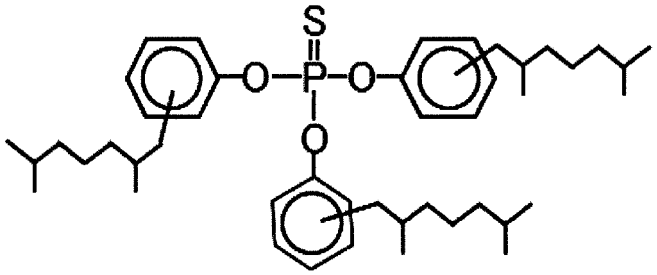
[Chem. 4]



Extreme pressure additive 3:

[0062] tris(2,4-C9-C10isoalkylphenyl)thiophosphate ester shown by the following structure

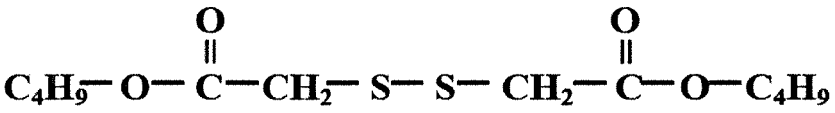
[Chem. 5]



Extreme pressure additive 4:

[0063] dibutyl dithioglycolate shown by the following structure

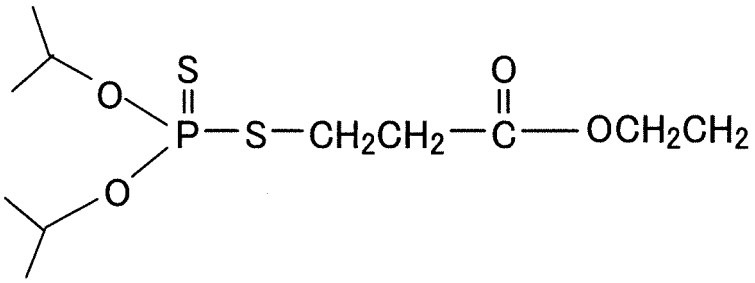
[Chem. 6]



Extreme pressure additive 5:

[0064] dithiophosphate ester shown by the following structure

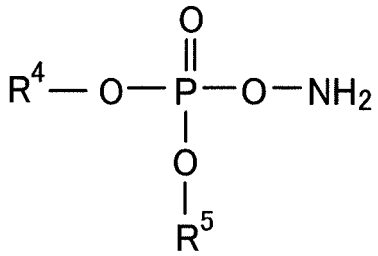
[Chem. 7]



Extreme pressure additive 6:

[0065] alkyl acid phosphate amine salt shown by the following structure

[Chem. 8]



wherein R^4 and R^5 each represent a hydrogen atom or an alkyl group.
Pour point depressant: polymethacrylate (weight average molecular weight: 69,000)
Detergent-dispersant: Ca alkyl salicylate
Rust inhibitor: Ca sulfonate
Metal deactivator: dialkylaminomethylbenzotriazole
Defoaming agent: silicone defoaming agent

Example 6 and Comparative Examples 7 and 8

[0066] The lubricating oil compositions E, J and K obtained in Examples 5 and Comparative Examples 5 and 6 were subjected to evaluation for the composition, the property, the rotating pressure vessel oxidation test (RPVOT), and the FZG gear test. The results are shown in Table 5.

Table 5

		Example 6	Comparative Example 7	Comparative Example 8
Lubricating oil composition		E	J	K
Kinetic viscosity (40°C) (mm^2/g)		46.1	47.9	45.6
Acid value (mgKOH/g)		0.22	1.35	0.06
Copper strip corrosion (100°C, 3 hours)		1(1B)	1(1B)	1(1B)
Sulfur content (ppm)		220	0.73%	-
Nitrogen content (ppm)		880	140	920
RPVOT (min)		1,900	247	1,850
ICP analysis (ppm)	P	262	482	167
	Zn	-	555	-
FZG marginal load step		12 <	11	7

[0067] The lubricating oil compositions were subjected to the oxidation stability test (modified IOT), and the test oils sampled within the period of from 0 to 960 hours were measured for the kinetic viscosity (40°C), the acid value, the rotating pressure vessel oxidation test (RPVOT), and the Millipore filter test value. The results are shown in Tables 6 and 7.

Table 6

	Example 6				
Oxygen blowing time (hr)	0	336	504	720	960
Kinetic viscosity (40°C) (mm2/g)	44.37	46.9	47.51	47.7	48
Acid value (mgKOH/g)	0.22	0.44	0.49	0.55	0.85

(continued)

	Example 6				
RPVOT (min)	1,900	1,486	929	932	798
Millipore filter test value (mg/100 mL)	0	39	29	100	70

Table 7

	Comparative Example 7				Comparative Example 8		
Oxygen blowing time (hr)	0	120	240	336	0	480	960
Kinetic viscosity (40°C) (mm^2/g)	47.94	48.56	58.99	86.42	44.43	47.11	48.23
Acid value (mgKOH/g)	1.35	1.49	8.53	23.7	0.09	0.38	0.77
RPVOT (min)	247	156	28	24	1,825	1,041	700
Millipore filter test value (mg/100 mL)	0	0.8	570	5,200	0	18	23

[0068] It is understood from Tables 6 and 7 that Comparative Example 7 shows a good result in the FZG gear test showing the extreme pressure property since ZnDTP was compounded as an extreme pressure additive, but shows a tendency of drastic increase in the acid value and the Millipore filter test value, which is not suitable for long-term use. It is also understood that Comparative Example 8 shows a poor result in the FZG gear test showing the extreme pressure property since an extreme pressure additive was not compounded, and thus is not suitable for the use as a lubricating oil for a compressor.

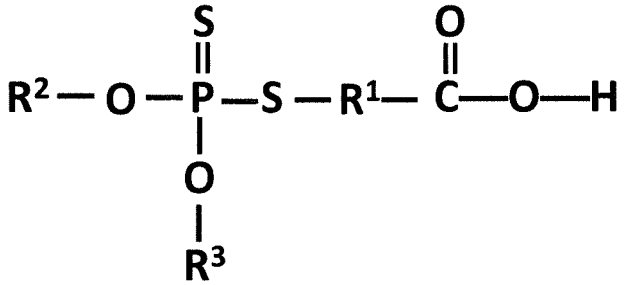
[0069] It is understood from the comparison with Comparative Examples 7 and 8 that Example 6 suppresses the formation of sludge to a practically favorable level while maintaining high oxidation stability for a prolonged period of time, and is capable of imparting excellent extreme pressure property.

Industrial Applicability

[0070] The lubricating oil composition for a rotary compressor of the present invention is capable of imparting high extreme pressure property while maintaining high oxidation stability, and thus may be favorably used particularly as a lubricating oil for a gear-driven rotary compressor, such as a screw compressor, a movable vane compressor, a scroll compressor, and a tooth compressor.

Claims

1. A lubricating oil composition for a rotary compressor, comprising (a) a base oil, (b) an antioxidant, and (c) a dithiophosphate ester compound represented by the following formula (I) in an amount of 0.05% by mass or more and less than 2.0% by mass based on the total amount of the composition:



(I)

wherein R^1 represents a linear or branched alkylene group having from 1 to 8 carbon atoms; and R^2 and R^3 each represent a hydrocarbon group having from 3 to 20 carbon atoms.

2. The lubricant oil composition for a rotary compressor according to claim 1, wherein the lubricating oil composition comprises (c) the dithiophosphate ester compound represented by the following formula (I) in an amount of more than 0.1% by mass and less than 2% by mass.

3. The lubricating oil composition for a rotary compressor according to claim 1 or 2, wherein R^1 represents a linear or branched alkylene group having from 1 to 8 carbon atoms; and R^2 and R^3 each represent a linear or branched alkylene group having from 3 to 20 carbon atoms.

4. The lubricating oil composition for a rotary compressor according to any one of claims 1 to 3, wherein (b) the antioxidant is at least one kind selected from a phosphorus compound, a phenol compound, a phenylamine compound, and a napthylamine compound.

5. The lubricating oil composition for a rotary compressor according to any one of claims 1 to 4, wherein the lubricating oil composition comprises the antioxidant in an amount of 0.01% by mass or more and 10% by mass or less.

6. The lubricant oil composition for a rotary compressor according to any one of claims 1 to 5, wherein the base oil is a mineral oil.

7. The lubricating oil composition for a rotary compressor according to any one of claims 1 to 6, wherein the rotary compressor is a gear-driven rotary compressor.

8. The lubricating oil composition for a rotary compressor according to any one of claims 1 to 7, wherein the rotary compressor is a screw compressor, a movable vane compressor, a scroll compressor, or a tooth compressor.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/083956

A. CLASSIFICATION OF SUBJECT MATTER
C10M169/04(2006.01)i, *C10M101/02*(2006.01)i, *C10M129/10*(2006.01)i, *C10M133/12*(2006.01)i, *C10M137/02*(2006.01)i, *C10M137/10*(2006.01)i, *C10N30/06*(2006.01)n, *C10N30/10*(2006.01)n, *C10N40/30*(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)
C10M169/04, C10M101/02, C10M129/10, C10M133/12, C10M137/02, C10M137/10, C10N30/06, C10N30/10, C10N40/30

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 1996-2014
Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2010-150562 A (Nippon Oil Corp.), 08 July 2010 (08.07.2010), claims; paragraphs [0002], [0062] to [0064]; examples (Family: none)	1-6 7,8
X Y	JP 2005-194416 A (Nippon Oil Corp.), 21 July 2005 (21.07.2005), claims; paragraphs [0002], [0127], [0128]; examples (Family: none)	1-6 7,8

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

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Date of the actual completion of the international search	Date of mailing of the international search report
23 January, 2014 (23.01.14)	04 February, 2014 (04.02.14)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/083956

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 2002-265971 A (Showa Shell Sekiyu Kabushiki Kaisha), 18 September 2002 (18.09.2002), claims; paragraphs [0012] to [0014]; table 5 & US 2004/0053794 A1 & EP 1354023 A1 & WO 2002/053687 A2	1-6 7,8
Y	JP 2008-537919 A (E.I. Du Pont de Nemours & Co.), 02 October 2008 (02.10.2008), entire text & US 2006/0245944 A1 & EP 1863663 A1 & WO 2006/102492 A1	7,8
Y	JP 2002-531755 A (American Standard Inc.), 24 September 2002 (24.09.2002), entire text & US 6068457 A & EP 1135612 A1 & WO 2000/032937 A1	7,8

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 02102945 A **[0004]**
- JP 2005139451 A **[0004]**