LUBRICANT COMPOSITION FOR ROTARY GAS COMPRESSOR AND ROTARY GAS COMPRESSOR FILLED WITH THE SAME

A lubricating oil composition for a rotary gas compressor has a kinematic viscosity of 5 mm²/s or less at 100 degrees C, a flash point of 200 degrees C or more and 5 volume % distillation temperature of 350 degrees C or more. The lubricating oil composition contains at least either one of a phosphorous extreme pressure agent and an antioxidant.
Description

Technical Field

[0001] The present invention relates to a lubricating oil composition for a rotary gas compressor and a rotary gas compressor filled with the same.

Background Art

[0002] A rotary gas compressor, which generates less vibration than a reciprocating gas compressor, is operated with a massive amount of a lubricating oil being injected, so that a temperature of discharged gas can be lowered. Among the rotary gas compressor, an oil-cooling screw compressor, which is a positive displacement type, has features of a rotary type as well as features of the positive displacement type. Owing to the features such as high efficiency, compact size and long-period continuous operation, the oil-cooling screw compressor has been widely used in the industry (for example, Patent Documents 1 and 2). A lubricating oil having a high kinematic viscosity of more than 5 mm²/s at 100 degrees C is typically used for such compressor.


Disclosure of the Invention

Problems to Be Solved by the Invention

[0004] Since such a typical rotary gas compressor (oil-cooling screw compressor) as disclosed in Patent Documents 1 and 2 has used the lubricating oil of high viscosity as described above, a driving power becomes excessive when the rotary gas compressor is operated. Resultantly, a sufficient performance for energy-saving has not been obtainable. Accordingly, an object of the invention is to provide a lubricating oil composition for a rotary gas compressor and a rotary gas compressor filled with the same, the lubricating oil composition having a sufficient lubricity performance as well as excellent capability of energy-saving and reducing a lubricating oil consumption.

Means for Solving the Problems

[0005] As a result of a dedicated studies for solving the problem, the inventors have found that a lubricating oil composition is particularly excellently applicable to a rotary gas compressor when a kinematic viscosity, a flash point and a distillation temperature of the lubricating oil composition are within a particular range, and then the invention have been achieved.

[0006] The invention provides a lubricating oil composition for a rotary gas compressor and a rotary gas compressor filled with the same as described below:

(1) a lubricating oil composition for a rotary gas compressor having a kinematic viscosity of 5 mm²/s or less at 100 degrees C; a flash point of 200 degrees C or more; and 5 volume % distillation temperature of 350 degrees C or more;
(2) the lubricating oil composition for the rotary gas compressor as described in (1), in which a kinematic viscosity at 40 degrees C is 28 mm²/s or less;
(3) the lubricating oil composition for the rotary gas compressor as described in (1) or (2), in which at least either one of a phosphorous extreme pressure agent and an antioxidant is contained;
(4) the lubricating oil composition for the rotary gas compressor as described in (3), in which the phosphorous extreme pressure agent is at least either one of an orthophosphoric ester and an amine salt of a phosphate ester;
(5) the lubricating oil composition for the rotary gas compressor as described in (3) or (4), in which the antioxidant is at least either one of an amine compound, a phosphorous compound, a sulfur compound and a phosphorous/sulfur containing compound; and
(6) A rotary gas compressor filled with the lubricating oil composition for the rotary gas compressor as described in any one of (1) to (5).

[0007] When the lubricating oil composition for the rotary gas compressor according to the above aspect of the invention is filled in the rotary gas compressor and the rotary gas compressor is operated, a sufficient lubricity performance is maintainable, while an energy-saving effect is excellent owing to a low kinematic viscosity. Further, owing to a low
evaporativity of the lubricating oil composition, an evaporation loss is small even when the rotary gas compressor is operated for long hours. The lubricating oil composition for the rotary gas compressor according to the above aspect of the invention is considerably effective particularly when being filled in an oil-cooling crew compressor.

Best Mode for Carrying Out the Invention

[0008] Embodiments of the invention will be described in detail below. A lubricating oil composition for a rotary gas compressor according to an aspect of the invention (referred to as "the composition" hereinafter) contains a lubricating base oil and an additive, the composition having a kinematic viscosity of 5 mm²/s or less at 100 degrees C, a flash point of 200 degrees C or more and 5 volume % distillation temperature of 350 degrees C or more. The lubricant base oil is not particularly limitative, but any oil typically used as a lubricant base oil can be used irrespective of a mineral oil or a synthetic oil.

Preferably, examples of the mineral oil may include paraffinic and naphthenic base oils which can be obtained by subjecting a lubricating oil fraction produced by atmospheric- and vacuum-distillation of a crude oil, to any suitable combination of refining processes selected from solvent-deasphalting, solvent-extracting, hydrocracking, solvent-dewaxing, catalytic-dewaxing, hydrorefining, sulfuric acid treatment and clay treatment.

[0009] Preferably, examples of the synthetic oil may include: a poly-alpha-olefin (1-octene oligomer, 1-decene oligomer and the like), a polybutene, an isoparaffin, an olefin copolymer (an ethylene-propylene copolymer and the like), an alkylbenzene, an alkyl napthalene, a monoester (butyl stearate and the like), a dibasic acid ester (ditridecyl glutarate, di-2-ethylhexyladipate, disodecyl adipate, ditridecyl adipate, di-2-ethylhexyl sebacate and the like), a trisacid ester (trimeric acid ester and the like), a polyol ester (trimethylol propane caplyrate, trimethylol propane pelargonate, pentaerythritol 2-ethylhexanoate, pentaerythritol pelargionate, and the like), a polyoxyalkylene glycol, a dialkyl diphenyl ether, an alkyl diphenyl sulfide, a polyphenyl ether, silicone oil (dimethyl silicone and the like) and a perfluoropolyether.

[0010] These mineral oils and synthetic oils may be singularly used, or two or more base oils selected from these oils may be mixed at any rate in use. The base oil of any viscosity may be used for the composition. However, in consideration of lubricity, cooling performance and friction loss at agitation, it is desirable to use the base oil with a kinematic viscosity of 1 to 10,000 mm²/s at 40 degrees C, preferably 5 to 100 mm²/s, more preferably 10 to 68 mm²/s. The base oil for the composition may be preferably selected from API (American Petroleum Institute) classification groups II to IV.

[0011] It is preferable that the lubricating oil composition for the rotary gas compressor according to the aspect of the invention contains at least either one of a phosphorous extreme pressure agent and an antioxidant. The phosphorous extreme pressure agent is preferably orthophosphoric esters, phosphate esters, acidic phosphate esters, acidic phosphite esters or an amine salt thereof. The orthophosphoric ester may be exemplified by a triaryl phosphate, a trialkyl phosphate, a trialkyl aryl phosphate, a triaryl alkyl phosphate and a trialkenyl phosphate, examples of which may include: a triphenyl phosphate, a tricresyl phosphate, a benzyl diphenyl phosphate, an ethyl diphenyl phosphate, a tributyl phosphate, an ethyl dibutyl phosphate, a cresyl diphenyl phosphate, a dicyresyl phenyl phosphate, an ethylenylphenyl phenyl phosphate, a propylphenyl diphenyl phosphate, a dipropylphenyl phenyl phosphate, a tripropylphenyl phosphate, a butylphenyl diphenyl phosphate, a dibutylphenyl phenyl phosphate, a tributylphenyl phosphate, a triethyl phosphate, a trinormal octyl phosphate, a tri(2-ethylhexyl) phosphate, a tridecyl phosphate, a trilauryl phosphate, a trimysteryl phosphate, a tripalmityl phosphate, a tristearyl phosphate, a trioleyl phosphate and the like.

[0012] Examples of the phosphite ester may include: a triethyl phosphite, a tributyl phosphite, a triphenyl phosphite, a tricresyl phosphite, a tri(nonylphenyl) phosphite, a tri(2-ethylhexyl) phosphite, a tridecyl phosphate, a trilauryl phosphate, a tristearyl phosphate, a trioleyl phosphate and the like. Examples of the acidic phosphite ester may include: a 2-ethylhexyl acid phosphate, a dinormal octyl acid phosphate, an ethyl acid phosphate, a butyl acid phosphate, an oleyl acid phosphate, a tetracosyl acid phosphate, an isodecyl acid phosphate, a lauryl acid phosphate, a tridecyl acid phosphate, a stearyl acid phosphate, an isostearyl acid phosphate and the like.

[0013] Examples of the acidic phosphate ester may include: a diethyl hydrogen phosphate, a dibutyl hydrogen phosphate, a dialkyl hydrogen phosphate, dioleoyl hydrogen phosphate, a distearoyl hydrogen phosphate, a diphenyl hydrogen phosphate, etc. Examples of amines to form the amine salt of the above compounds may include: a mono-substituted amine, a di-substituted amine or a tri-substituted amine represented by the following formula (1). The alkyl group or the alkenyl group having 3 to 30 carbon atoms represented by R in the formula (1) may be linear, branched or cyclic.

\[ \text{R}_n \text{NH}_3 \cdot n \]  

(1)

In the formula: R represents an alkyl group or an alkenyl group having 3 to 30 carbon atoms, preferably 4 to 18 carbon atoms, an aryl group or an arylalkyl group having 6 to 30 carbon atoms, preferably 6 to 15 carbon atoms, or a hydroxyalkyl...
group having 2 to 30 carbon atoms, preferably 2 to 18 carbon atoms; and n represents 1, 2 or 3. When plural units of R are contained, the plural units of R may be mutually the same or different.

[0014] Examples of the mono-substituted amine may include: a butyl amine, a pentyl amine, a hexyl amine, a cyclohexyl amine, an octyl amine, a lauryl amine, a stearyl amine, an oleyl amine, a benzyl amine and the like. Examples of the di-substituted amine may include: a dibutyl amine, a dipentyl amine, a dihexyl amine, a dicyclohexyl amine, a dioctyl amine, a dilauryl amine, a distearyl amine, an dioleoyl amine, a dibenzyl amine, a stearyl monoethanol amine, a decyl monoethanol amine, a hexyl monopropanol amine, a benzyl monoethanol amine, a phenyl monopropanol amine, and the like. Examples of the tri-substituted amine may include: a tributyl amine, a tripentyl amine, a trihexyl amine, a tricyclohexyl amine, a trioctyl amine, a trilauryl amine, a trioleyl amine, a tribenzyl amine, a dioleoyl monoethanol amine, a dilauryl monopropanol amine, a dioctyl monoethanol amine, a dihexyl monopropanol amine, a dibutyl monopropanol amine, an oleyl diethanol amine, a stearyl dipropanol amine, a lauryl diethanol amine, an octyl dipropanol amine, a butyl diethanol amine, a benzyl diethanol amine, a phenyl diethanol amine, a tolyl dipropanol amine, a xylol diethanol amine, a triethanol amine, a trip propane amine, a tertiary dodecyl amine and the like.

Among the antioxidants, diethyl[3,5-bis(2,6-di-methyl-phenyl)-2-sulfanyl]phosphonate and dilauryldiphenylamine are preferable in perspective of heat resistance.

In view of blending effects and an economical aspect, a content of the extreme pressure agent is typically approximately 0.01 to 30 mass% of the total amount of the lubricating oil composition, preferably 0.01 to 10 mass%.

[0015] Antioxidants typically used for a lubricating oil such as an amine compound, a phosphorous compound, a sulfur compound, a phosphorous/sulfur containing compound and a phenol compound can be used as the antioxidant. Examples of the amine compound may include: a monoalkyldiphenylamine compound such as mono-octyl diphenylamine and monononyldiphenylamine; a dialkyl diphenylamine compound such as 4,4'-dibutyl diphenylamine, 4,4'-dipentyl diphenylamine, 4,4'-dihexyl diphenylamine, 4,4'-dioctyl diphenylamine and 4,4'-diononyldiphenylamine; a polyaalkyldiphenylamine compound such as tetrabutyl diphenylamine, tetrahexyl diphenylamine, tetractyle diphenylamine 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, dodecylphenyl-α-naphthylamine and the like.

Examples of the phenol compound may include: alkyl phenols such as 2,6-di-tert-butyl-4-methylphenol and bisphenols such as methylene-4,4-bis(2,6-di-tet-tert-butyl-4-methylphenol).

Among the antioxidants, diethyl[3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl]methylphosphonate is preferable in perspective of heat resistance. A content of the antioxidant is typically approximately 0.01 to 10 mass% of the total amount of the lubricating oil composition, preferably 0.03 to 5 mass%.

[0017] The composition, which is preferably formed of the above-described base oil and various additives, has a kinematic viscosity (according to JIS (Japanese Industrial Standard) K 2283) of 5 mm²/s or less at 100 degrees C, preferably 4.95 mm²/s or less, more preferably 4.5 mm²/s or less. When the kinematic viscosity at 100 degrees C exceeds 5 mm²/s, the driving power of the rotary gas compressor is excessive.

A flash point of the composition (according to C.O.C, JIS K 2265) is 200 degrees C or more, preferably 210 degrees C or more. When the flash point is less than 200 degrees C, there is an increasing danger of flashing in operation of the rotary gas compressor filled with the composition.

5 volume % distillation temperature of the composition (according to JIS K 2254) is 350 degrees C or more, preferably 370 degrees C or more, more preferably 390 degrees C or more. In case where 5 volume % distillation temperature is less than 350 degrees C, lubricating oil consumption unpreferably increases when the rotary gas compressor is operated for long hours.

The rotary gas compressor filled with the above composition as a lubricating oil consumes less the lubricating oil and maintains a sufficient lubricity, thereby exhibiting an excellent energy-saving effect. Particularly, when the composition is filled in an oil-cooling screw compressor, the composition exhibits considerably excellent cooling performance and heat resistance.

The kinematic viscosity of the composition at 40 degrees C is preferably 28 mm²/s or less, more preferably 25 mm²/s or less, more preferably 23 mm²/s or less. When the kinematic viscosity at 40 degrees C exceeds 28 mm²/s, the driving power of the rotary gas compressor is excessive.

[0018] The lubricating oil composition for the rotary gas compressor according to the aspect of the invention may be further added with an oiliness agent, a rust inhibitor, a detergent dispersant, a metal deactivator and an antifoaming agent, a cetane improver, a fuel improver, a detergent dispersant, a metal deactivator and an antifoaming agent.
agent as needed.
The oiliness agent may be exemplified by 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 ester compound is preferable among these compounds since the ester compound can provide both heat resistance and lubricity.

In view of blending effects, a content of the oiliness agent is typically approximately 0.1 to 30 mass% of the total amount of the lubricating oil composition, preferably 0.5 to 10 mass%.

[0019] The rust inhibitor may be exemplified by a metal sulfonate, aliphatic amines, an organic phosphite ester, an organic phosphate ester, an organic metal sulfonate, an organic metal phosphate, an alkylsuccinic acid ester, a multivalent alcohol ester and the like. In view of blending effects, a content of the rust inhibitor is typically approximately 0.01 to 10 mass% of the total amount of the lubricating oil composition, preferably 0.05 to 5 mass%.

[0020] The detergent dispersant may be exemplified by a metal sulfonate, a metal salicylate, a metal phenate, a metal phosphonate and succinimide. A metallic detergent dispersant is preferable among these in perspective of detergent dispersivity and demulsification performance.

In view of blending effects, a content of the detergent dispersant is typically approximately 0.1 to 30 mass% of the total amount of the lubricating oil composition, preferably 0.5 to 10 mass%.

[0021] The metal deactivator may be exemplified by benzotriazoles and thiadiazoles. In view of blending effects, a content of the metal deactivator is typically approximately 0.01 to 10 mass% of the total amount of the lubricating oil composition, preferably 0.01 to 1 mass%.

The antifoaming agent may be exemplified by methyl silicone oil, fluorosilicone oil and polyacrylates. In view of blending effects, a content of the antifoaming agent is typically approximately 0.0005 to 0.01 mass% of the total amount of the lubricating oil composition.

Examples

[0022] The invention will be further described in detail below with reference to Examples and Comparatives, which by no means limit scope of the invention.

[Examples 1 to 6 and Comparatives 1 and 2]

[0023] Additives were added to predetermined base oils (API classification groups I to IV) to prepare lubricating oil compositions having respective properties. Maximum loading capacity, wear resistance, evaporation amounts and actual power consumption were evaluated. A method of examining properties of the lubricating oil compositions and a method for evaluating respective properties are shown below. Results are shown in Table 1.

(1) Properties of Lubricating Oil Composition

[0024] A method of examining each property (standard) is shown below.

(1.1) Kinematic Viscosity (100 degrees C, 40 degrees C): according to JIS K 2283
(1.2) Viscosity Index: according to JIS K 2283
(1.3) Density (at 15 degrees C): according to JIS K 2249
(1.4) Flash Point (C.O.C): according to JIS K 2265
(1.5) Distillation Property (5 volume % distillation temperature, 10 volume % distillation temperature): according to JIS K 2254 (Distillation was conducted at reduced pressure of 133MPa and an obtained value was converted to a value at atmospheric pressure.)

(2) Evaluation Items and Evaluation Method

[0025] (2.1) Maximum Loading Capacity Test (Shell EP Test)
A test was conducted at a rotational speed of 1,800 rpm and at room temperature according to ASTM D2783. A load wear index (LWI) was obtained from a last non-seizure load (LNL) and a weld load (WL). The larger this value is, the better a load resistance is.

(2.2) Wear Resistance Test (Shell Wear Test)
A test was conducted under conditions of a load of 392N, a rotational speed of 1,200 rpm, an oil temperature of 80 degrees C and a testing time of 60 minutes according to ASTM D2783. An average wear track diameter was
(2.3) Film Residue Test
In a vessel based on JIS K 2540, a sample of 1g was filled. Air was flowed into the vessel under an atmosphere at a constant temperature of 150 degrees C with a flowing volume of 10 L/h for 6 hours. After the test, a mass of the sample (evaporation residue) was measured. An amount of the evaporation residue relative to the original amount of the sample was expressed by mass percentage.

(2.4) Actual Power Consumption
A commercially available oil-cooling screw compressor (motor output: 22kW, oil quantity: 10L, intake gas: air, intake pressure: atmospheric pressure, intake temperature: 25 degrees C) was used as a rotary gas compressor to measure effective power consumption of the compressor motor when continuously operated for three hours at an average oil temperature of 80 degrees C. The measurement was conducted by a clamp-on-sensor type power meter that is commercially available.

The measurement was conducted in two operation modes as follows.

Operation Mode I: discharge pressure of 0.65 MPa
Operation Mode II: discharge pressure of 0.24 MPa
<table>
<thead>
<tr>
<th></th>
<th>Example 1</th>
<th>Example 2</th>
<th>Example 3</th>
<th>Example 4</th>
<th>Example 5</th>
<th>Example 6</th>
<th>Comparative 1</th>
<th>Comparative 2</th>
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<td><strong>base oil (mass%)</strong></td>
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<td>remnant</td>
<td>remnant</td>
<td>remnant</td>
<td>remnant</td>
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<tr>
<td>API GIII (100 neutral)</td>
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<tr>
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<td>218</td>
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<td>Evaluation</td>
<td>Example 1</td>
<td>Example 2</td>
<td>Example 3</td>
<td>Example 4</td>
<td>Example 5</td>
<td>Example 6</td>
<td>Comparative 1</td>
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<td>164</td>
<td>301</td>
<td>307</td>
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<td>Film residue (mass%)</td>
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<td>95.5</td>
<td>90.2</td>
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<td>67.756</td>
<td>68.730</td>
<td>69.280</td>
<td>67.613</td>
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</table>

*1 diethyl[3,5-bis(1,1-dimethylethyl)-4-hydroxyphenyl]methyl]phosphonate
*2 trimethylol propane trialkyl ester (in which an alkyl group is a mixture of C8 and C10)
*3 a package of a metallic detergent dispersant, metallic rust inhibitor and antifoaming agent
[Evaluation Results]

[0027] As shown in Table 1, the results of Examples 1 to 6 using the composition exhibited excellent lubricity performance as a lubricating oil as well as excellent energy-saving effect and consumed less lubricating oil. In contrast, in Comparative 1, a kinematic viscosity at 100 degrees C is high and power consumption of a rotary gas compressor is large. Moreover, a consumption of a lubricating oil is rather large irrespective of the high kinematic viscosity at 100 degrees C. In Comparative 2, a consumption of a lubricating oil becomes excessive due to a low 5 volume % distillation temperature, thereby making it difficult to operate a rotary gas compressor for long hours.

Industrial Applicability

[0028] The present invention is preferably applicable as a lubricating oil for a rotary gas compressor.

Claims

1. A lubricating oil composition for a rotary gas compressor, comprising:
   - a kinematic viscosity of 5 mm²/s or less at 100 degrees C;
   - a flash point of 200 degrees C or more; and
   - 5 volume % distillation temperature of 350 degrees C or more.

2. The lubricating oil composition for the rotary gas compressor according to claim 1, wherein a kinematic viscosity at 40 degrees C is 28 mm²/s or less.

3. The lubricating oil composition for the rotary gas compressor according to claim 1 or 2, wherein at least either one of a phosphorous extreme pressure agent and an antioxidant is contained.

4. The lubricating oil composition for the rotary gas compressor according to claim 3, wherein the phosphorous extreme pressure agent is at least either one of an orthophosphoric ester and an amine salt of a phosphate ester.

5. The lubricating oil composition for the rotary gas compressor according to claim 3 or 4, wherein the antioxidant is at least one of an amine compound, a phosphorous compound, a sulfur compound and a phosphorous/sulfur containing compound.

6. A rotary compressor filled with the lubricating oil composition for the rotary gas compressor according to any one of claims 1 to 5.
**INTERNATIONAL SEARCH REPORT**

**Classification of Subject Matter**

C10M171/02 (2006.01), C10M137/04 (2006.01), C10M137/08 (2006.01),
C10M169/04 (2006.01), C10N20/00 (2006.01), C10N20/02 (2006.01),
C10N40/30 (2006.01)

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

**Fields Searched**

Minimum documentation searched (classification system followed by classification symbols):
C10M171/02, C10M137/04, C10M137/08, C10M169/04, C10N20/00, C10N20/02,
C10N40/30

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

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

**Documents Considered to be Relevant**

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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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**Date of the actual completion of the international search**

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REFERENCES CITED IN THE DESCRIPTION

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