

## DESCRIPTION

### Title of Invention

LUBRICATION METHOD

### Technical Field

5 [0001] The present invention relates to a lubrication method.

### Background Art

[0002] In a mechanical apparatus or the like including a metal material as a sliding member, various lubricating agents are used in order to lubricate the sliding member. As the lubricating agent, lubricating oil, grease, and the like, in which various additives are compounded as necessary, are used.

[0003] Recently, the use of a resin material as the sliding member has been considered in many applications, from the viewpoint of weight saving of parts, processing easiness, and the like, based on fuel saving and the like. However, the resin material may cause degradation in mechanical strength, wear, breakage, and the like, compared to the metal material.

[0004] For example, in Patent Literature 1, it is disclosed that a lubricating agent (refrigerant oil) that contains at least one type selected from mineral oil, a synthetic alicyclic hydrocarbon compound, and a synthetic aromatic hydrocarbon compound, as a main component, and contains base oil of which a kinetic viscosity at 40°C is 1 to 8 mm<sup>2</sup>/s is applied to a sliding portion containing polyphenylene sulfide or a sliding portion including a polymer coating film or an inorganic coating film.

### 25 Citation List

### Patent Literature

[0005] Patent Literature 1: International Publication WO 2007/058072

### **Summary of Invention**

#### **Technical Problem**

5 [0006] In a case of using the resin material as the sliding member (in particular, a member containing an engineering plastic), it is essential to improve slidability, compared to a case of using the metal material. However, a lubrication method of the related art is not sufficient from the viewpoint of improving the slidability, and there is room for improvement.

10 [0007] The present invention has been made in consideration of such circumstances, and an object thereof is to provide a lubrication method that is capable of improving slidability in a case of using a resin material as a sliding member.

#### **Solution to Problem**

15 [0008] The present invention provides a lubrication method of lubricating a pair of sliding members by using a lubricating oil composition. In the lubrication method, at least one of the pair of sliding members is a member containing an engineering plastic, and the lubricating oil composition contains a lubricating base oil, and at least one type of wear inhibitor selected from the group consisting of a wear  
20 inhibitor containing phosphorus but not sulfur as a constituent element, a wear inhibitor containing sulfur but not phosphorus as a constituent element, and a wear inhibitor containing phosphorus and sulfur as a constituent element. According to such a lubrication method, in a case where a resin material is used as a sliding member from the viewpoint of  
25 weight saving, it is possible to improve wear resistance while reducing a friction coefficient between the sliding members and to improve

slidability.

[0009] It is preferable that one of the pair of sliding members is a member containing an engineering plastic, and the other is a member containing an iron-based material.

## 5      **Advantageous Effects of Invention**

[0010] According to the present invention, a lubrication method that is capable of improving slidability in a case of using a resin material as a sliding member is provided.

## **Description of Embodiments**

10      [0011] Hereinafter, an embodiment of the present invention will be described in detail. Here, the present invention is not limited to the following embodiment.

         [0012] A lubrication method of one embodiment is a method of lubricating a pair of sliding members (that relatively move facing each  
15      other) by using a lubricating oil composition.

         [0013] In the lubrication method of this embodiment, at least one of the pair of sliding members is a member containing an engineering plastic. In general, the engineering plastic indicates a plastic of which heat resistance is higher than or equal to 100°C, strength is greater than or  
20      equal to 50 MPa, and a bending elastic modulus is greater than or equal to 2.4 GPa. The engineering plastic further includes a super engineering plastic of which heat resistance is higher than or equal to 150°C.

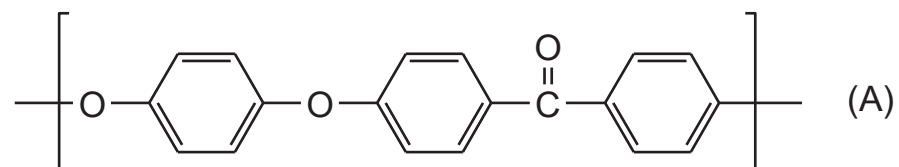
         [0014] The engineering plastic is not particularly limited, and examples thereof include an amorphous resin such as polycarbonate (PC) and  
25      modified polyphenylene ether (m-PPE), a (semi)crystalline resin such as polyacetal (POM), polyamide (PA), polybutylene terephthalate (PBT),

and polyethylene terephthalate (PET), and the like. Among them, the engineering plastic may be polyacetal (POM) or polyamide (PA).

[0015] The engineering plastic may be a super engineering plastic. The super engineering plastic is not particularly limited, and examples thereof include an amorphous resin such as polyphenyl sulfone (PPSU), polysulfone (PSF), polyarylate (PAR), polyether imide (PEI), and polyamide imide (PAI), a (semi)crystalline resin such as polyether ether ketone (PEEK), polyphenylene sulfide (PPS), polyether sulfone (PES), a liquid crystal polymer (LCP), polyvinylidene fluoride (PVDF), and polytetrafluoroethylene (PTFE), and the like. Among them, the super engineering plastic may be polyether ether ketone (PEEK).

[0016] PEEK is one type of semicrystalline polymer having a structure in which benzene rings are linked by an ether bond or a carbonyl group. PEEK, for example, is a polymer having a structural unit represented by Formula (A) described below.

[0017]



[0018] A number average molecular weight  $M_n$  of PEEK, for example, may be 20000 to 50000, and a weight average molecular weight  $M_w$  of PEEK, for example, may be 60000 to 150000.  $M_w/M_n$  indicating a molecular weight distribution may be 2 to 4. Note that, the number average molecular weight  $M_n$  and the weight average molecular weight  $M_w$  indicate a numerical value measured by a GPC method and are a relative value based on polystyrene.

[0019] The sliding member may be a member containing an engineering plastic, and from the viewpoint of further improving slidability, the sliding member may be a member containing a solid lubricating agent, a reinforced fiber, a filler, an additive, and the like, as other components except for the engineering plastic.

[0020] Examples of the solid lubricating agent include boron nitride, molybdenum disulfide, a fluorine resin, a carbon-based solid lubricating agent (graphite, carbon black, and the like), and the like.

[0021] In a case where the sliding member contains the solid lubricating agent, the content of the solid lubricating agent may be 0.1 to 30 mass% or 0.5 to 20 mass%, on the basis of the total amount of the sliding member. In a case where the content of the solid lubricating agent is less than or equal to 30 mass%, on the basis of the total amount of the sliding member, a failure is less likely to occur in a step of preparing a pellet with a compound, and a significant decrease in mechanical properties such as impact strength as a sliding member can be prevented. In a case where the content of the solid lubricating agent is greater than or equal to 0.1 mass%, on the basis of the total amount of the sliding member, an effect of including the solid lubricating agent can be sufficiently obtained.

[0022] Examples of the reinforced fiber include a glass fiber, a carbon fiber, an aramid fiber, a fibrous material such as various whiskers, and the like. Among them, the reinforced fiber is preferably a glass fiber, a carbon fiber, or an aramid fiber since the slidability can be further improved, and the reinforced fiber is more preferably a carbon fiber or an aramid fiber since the wear of the sliding member at the time of sliding can be further suppressed.

[0023] In a case where the sliding member contains the reinforced fiber, the content of the reinforced fiber may be 0.1 to 80 mass% or 0.5 to 70 mass%, on the basis of the total amount of the sliding member. In a case where the content of the reinforced fiber is less than or equal to 80 mass%, on the basis of the total amount of the sliding member, a failure is less likely to occur in a step of preparing a pellet with a compound, and a significant decrease in mechanical properties such as impact strength as a sliding member can be prevented. In a case where the content of the reinforced fiber is greater than or equal to 0.1 mass%, on the basis of the total amount of the sliding member, an effect of including the reinforced fiber can be sufficiently obtained.

[0024] Examples of the filler include talc, mica, glass flake, clay, sericite, calcium carbonate, calcium sulfate, calcium silicate, silica, alumina, aluminum hydroxide, calcium hydroxide, potassium titanate, titanium oxide, a fluorocarbon resin fiber, a fluorocarbon resin, barium sulfate, various whiskers, and the like.

[0025] Examples of the additive include a colorant, a dispersant, a plasticizer, an oxidant inhibitor, a curing agent, a flame retarder, a heat stabilizer, an ultraviolet absorber, an antistatic agent, a surfactant, and the like.

[0026] The total content of the filler and the additive is not particularly limited, and may be less than or equal to 10 mass% or less than or equal to 5 mass%, on the basis of the total amount of the sliding member.

[0027] The sliding member may contain a polymer other than the engineering plastic within a range not significantly impairing the effects of the present invention. Examples of the polymer other than the

engineering plastic include polyethylene, polystyrene, polypropylene, polyvinyl chloride, a phenolic resin, an epoxy resin, and the like.

5 [0028] In the pair of sliding members that relatively move facing each other, both of the sliding members may be a member containing an engineering plastic, and one of the sliding members may be a member containing an engineering plastic, and the other may be a member other than the member containing the engineering plastic. Examples of such a member include a metal-based material such as an iron-based material, an aluminum-based material, and a magnesium-based material, a non-  
10 metal-based material such as a polymer other than an engineering plastic, a plastic, and carbon, and the like. Among them, the other of the sliding members is preferably a member containing a metal-based material, and is more preferably a member containing an iron-based material, since the slidability can be further improved.

15 [0029] In a case where one of the sliding members is the member containing the engineering plastic, and the other is the member containing the metal-based material, the lubrication method of this embodiment is capable of improving the slidability even in a case of a member containing a metal-based material having large surface roughness (arithmetic average roughness Ra). The surface roughness (the  
20 arithmetic average roughness Ra) of the member containing the metal-based material, for example, may be greater than or equal to 0.05  $\mu\text{m}$ , greater than or equal to 0.1  $\mu\text{m}$ , or greater than or equal to 0.3  $\mu\text{m}$ .

25 [0030] The lubrication method of this embodiment lubricates the sliding member described above by using a lubricating oil composition. The lubricating oil composition contains a lubricating base oil and a

predetermined wear inhibitor.

[0031] Examples of the lubricating base oil include hydrocarbon oil, oxygen-containing oil, and the like. Examples of the hydrocarbon oil include mineral oil-based hydrocarbon oil, synthetic hydrocarbon oil, and the like. Examples of the oxygen-containing oil include ester, ether, carbonate, ketone, silicone, polysiloxane, and the like. Only one type of the lubricating base oil may be used, or two or more types thereof may be used in combination at an arbitrary ratio. It is preferable that the lubricating base oil contains hydrocarbon oil (mineral oil-based hydrocarbon oil or synthetic hydrocarbon oil).

[0032] Examples of the mineral oil-based hydrocarbon oil include paraffin-based mineral oil (normal paraffin, isoparaffin, and the like), naphthene-based mineral oil, aromatic-based mineral oil, and the like, which are obtained by refining a lubricating oil distillate obtained by distilling crude oil under an ordinary pressure and/or under a reduced pressure with only one or a suitable combination of two or more of refining treatments such as solvent deasphalting, solvent extraction, hydrocracking, solvent dewaxing, catalytic dewaxing, hydrotreating, sulfuric acid washing, and a white earth treatment.

[0033] Examples of the synthetic hydrocarbon oil include alkyl benzene, alkyl naphthalene, poly $\alpha$ -olefin (PAO), polybutene, an ethylene- $\alpha$ -olefin copolymer, and the like.

[0034] A kinetic viscosity of the lubricating base oil at 40°C, for example, may be greater than or equal to 1 mm<sup>2</sup>/s, greater than or equal to 5 mm<sup>2</sup>/s, or greater than or equal to 10 mm<sup>2</sup>/s, and may be less than or equal to 1000 mm<sup>2</sup>/s, less than or equal to 600 mm<sup>2</sup>/s, less than or equal to 200

mm<sup>2</sup>/s, less than or equal to 100 mm<sup>2</sup>/s, or less than or equal to 50 mm<sup>2</sup>/s, from the viewpoint of the slidability. Note that, herein, the kinetic viscosity at 40°C indicates a kinetic viscosity at 40°C that is measured on the basis of JIS K 2283:2000.

5 [0035] Other physical properties of the lubricating base oil that is used in the lubrication method of this embodiment, such as a kinetic viscosity at 100°C, a viscosity index, a NOACK evaporation amount, a flash point, and a pour point, can be suitably set.

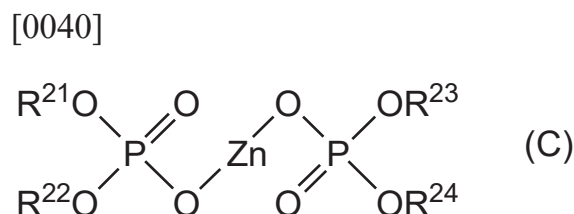
10 [0036] The content of the lubricating base oil, for example, may be greater than or equal to 70 mass%, greater than or equal to 80 mass%, greater than or equal to 85 mass%, greater than or equal to 90 mass%, greater than or equal to 95 mass%, or greater than or equal to 97 mass%, and may be less than or equal to 99.9 mass%, less than or equal to 99.7 mass%, or less than or equal to 99.5 mass%, on the basis of the total  
15 amount of the lubricating oil composition.

[0037] The wear inhibitor is at least one type selected from the group consisting of a wear inhibitor containing phosphorus but not sulfur as a constituent element (hereinafter, may be referred to as a "first wear inhibitor"), a wear inhibitor containing sulfur but not phosphorus as a  
20 constituent element (hereinafter, may be referred to as a "second wear inhibitor"), and a wear inhibitor containing phosphorus and sulfur as a constituent element (hereinafter, may be referred to as a "third wear inhibitor").

[0038] Examples of the first wear inhibitor include zinc dialkyl  
25 phosphate; phosphite ester (mono(alkyl or aryl) phosphite, di(alkyl or aryl) phosphite, tri(alkyl or aryl) phosphate, and the like) (phosphite);

phosphate ester (mono(alkyl or aryl) phosphate, di(alkyl or aryl) phosphate, tri(alkyl or aryl) phosphate, and the like) (phosphate); an amine salt, a metal salt, and a derivative of phosphate ester or phosphite ester; condensed phosphate ester; phosphonate ester, and the like. The first wear inhibitor, for example, may be phosphate ester (phosphate) or a metal salt thereof.

[0039] A zinc salt of dialkyl phosphate (the zinc dialkyl phosphate), for example, may be a compound represented by Formula (C) described below.



[0041] In Formula (C),  $\text{R}^{21}$  to  $\text{R}^{24}$  each independently indicates a straight-chain or branched-chain alkyl group. The number of carbon atoms of the alkyl group may be greater than or equal to 1 or greater than or equal to 3, and may be less than or equal to 24, less than or equal to 12, or less than or equal to 8.

[0042] Examples of the phosphite ester include di(alkyl or aryl) phosphite such as dibutyl phosphite, dipentyl phosphite, dihexyl phosphite, diheptyl phosphite, dioctyl phosphite, dinonyl phosphite, didecyl phosphite, diundecyl phosphite, didodecyl phosphite, dioleyl phosphite, diphenyl phosphite, and dicresyl phosphite, tri(alkyl or aryl) phosphite such as tributyl phosphite, tripentyl phosphite, trihexyl phosphite, triheptyl phosphite, trioctyl phosphite, trinonyl phosphite, tridecyl phosphite, triundecyl phosphite, tridodecyl phosphite, trioleyl

phosphite, triphenyl phosphite, and tricresyl phosphate, and the like.

The alkyl group may be a straight-chain alkyl group, may be a branched-chain alkyl group, or may have an unsaturated bond.

[0043] Examples of the phosphate ester include di(alkyl or aryl) phosphate such as diethyl phosphate, dibutyl phosphate, dipentyl phosphate, dihexyl phosphate, diheptyl phosphate, dioctyl phosphate, dinonyl phosphate, didecyl phosphate, diundecyl phosphate, didodecyl phosphate, dioleyl phosphate, diphenyl phosphate, and dicresyl phosphate, tri(alkyl or aryl) phosphate such as tributyl phosphate, tripentyl phosphate, trihexyl phosphate, triheptyl phosphate, trioctyl phosphate, trinonyl phosphate, tridecyl phosphate, triundecyl phosphate, tridodecyl phosphate, tritridecyl phosphate, tritetradecyl phosphate, tripentadecyl phosphate, trihexadecyl phosphate, triheptadecyl phosphate, trioctadecyl phosphate, trioleyl phosphate, triphenyl phosphate, tricresyl phosphate, tri(ethyl phenyl) phosphate, tri(propyl phenyl) phosphate, tri(butyl phenyl) phosphate, trixylenyl phosphate, cresyl diphenyl phosphate, and xylenyl diphenyl phosphate, and the like. The alkyl group may be a straight-chain alkyl group, may be a branched-chain alkyl group, or may have an unsaturated bond.

[0044] Examples of the condensed phosphate ester include resorcinol bis(diphenyl phosphate), resorcinol bis(dixylenyl phosphate), bisphenol A bis(diphenyl phosphate), and the like.

[0045] Examples of the phosphonate ester include dialkyl phosphonoacetic acid, dialkyl hydroxymethyl phosphonate, dialkyl hydroxyethyl phosphonate, dialkyl hydroxyundecyl phosphonate, and the like. The alkyl group of phosphonate ester, for example, may be a

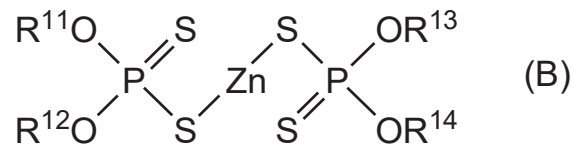
straight-chain or branched-chain aliphatic group having 1 to 20 carbon atoms, and the like.

[0046] Examples of the second wear inhibitor include dithiocarbamate, zinc dithiocarbamate, molybdenum dithiocarbamate (MoDTC), disulfide, sulfurized olefin, sulfurized grease, and the like. The second wear inhibitor, for example, may be sulfurized olefin.

[0047] Examples of the third wear inhibitor include zinc dialkyl dithiophosphate (ZnDTP); thiophosphite ester; dithiophosphite ester; trithiophosphite ester; thiophosphate ester; dithiophosphate ester; trithiophosphate ester; an amine salt, a metal salt, a derivative of thiophosphite ester, dithiophosphite ester, trithiophosphite ester, thiophosphate ester, dithiophosphate ester, or trithiophosphate ester, and the like. The third wear inhibitor, for example, may be zinc dialkyl dithiophosphate (ZnDTP).

[0048] The zinc dialkyl dithiophosphate (ZnDTP), for example, may be a compound represented by Formula (B) described below.

[0049]



[0050] In Formula (B), R<sup>11</sup> to R<sup>14</sup> each independently indicates a straight-chain or branched-chain alkyl group. The number of carbon atoms of the alkyl group may be greater than or equal to 1 or greater than or equal to 3, or may be less than or equal to 24, less than or equal to 12, or less than or equal to 8.

[0051] The wear inhibitor is at least one type selected from the group

consisting of the first wear inhibitor, the second wear inhibitor, and the third wear inhibitor. The wear inhibitor is preferably the first wear inhibitor or the third wear inhibitor.

5 [0052] The content of the wear inhibitor, for example, may be greater than or equal to 0.01 mass%, greater than or equal to 0.05 mass%, greater than or equal to 0.1 mass%, greater than or equal to 0.3 mass%, or greater than or equal to 0.5 mass%, and may be less than or equal to 20 mass%, less than or equal to 15 mass%, less than or equal to 10 mass%, less than or equal to 5 mass%, or less than or equal to 3 mass%, on the basis of the  
10 total amount of the lubricating oil composition.

[0053] The lubricating oil composition may further contain an arbitrary additive for lubricating oil, which is generally used, in accordance with the purpose. Examples of such an additive for lubricating oil include an  
15 oxidant inhibitor, an antifoaming agent, a metal deactivator, a viscosity index improver, a pour-point depressant, a detergent-dispersant, an acid scavenger, an antirust agent, and the like. The content of such an additive for lubricating oil, for example, may be 0.1 to 20 mass%, on the basis of the total amount of the lubricating oil composition.

[0054] A kinetic viscosity of the lubricating oil composition at 40°C, for  
20 example, may be greater than or equal to 1 mm<sup>2</sup>/s, greater than or equal to 5 mm<sup>2</sup>/s, or greater than or equal to 10 mm<sup>2</sup>/s, and may be less than or equal to 1000 mm<sup>2</sup>/s, less than or equal to 600 mm<sup>2</sup>/s, less than or equal to 200 mm<sup>2</sup>/s, less than or equal to 100 mm<sup>2</sup>/s, or less than or equal to 50 mm<sup>2</sup>/s, from the viewpoint of the slidability.

25 [0055] Other physical properties of the lubricating oil composition that is used in the lubrication method of this embodiment, such as a kinetic

viscosity at 100°C, a viscosity index, a NOACK evaporation amount, a flash point, and a pour point, can be suitably set.

[0056] The lubrication method according to this embodiment can be applied to a lubrication system of various apparatus. Examples of such

5 a lubrication system include a lubrication system for lubricating a portion that requires lubricating properties, in a mechanical apparatus such as a transport machine such as an (electric) vehicle, a train, and an aircraft, a working machine, an industrial machine such as a robot, home electronics such as a washing machine, a refrigerator, a room-air conditioner, and a  
10 vacuum cleaner, and a precision machine such as a clock and a camera, and the like. Examples of the portion that requires the lubricating properties include a portion in which parts slide in contact with each other (a sliding portion) such as a gear, a bearing, a pump, a vane/a rotor, and a piston ring, and the like. Examples of the mechanical apparatus  
15 including the sliding portion include an engine, a gearbox, a compressor, a hydraulic unit, a motor, and the like. Examples of the mechanical apparatus including the sliding portion also include a compression machine system including various refrigerants, and the like.

[0057] In the lubrication system, a method of supplying the lubricating  
20 oil composition to the sliding member is not particularly limited. The lubrication system, for example, may be a system including a reservoir containing the lubricating oil composition, and a supply unit supplying the lubricating oil composition to the sliding member from the reservoir. The supply unit may be a circulation type supply unit supplying the  
25 lubricating oil composition to the sliding member by supply means such as a pump. The lubrication system may be a system impregnating the

sliding member with the lubricating oil composition. The lubrication system may be a system in which a container including the sliding member is filled with the lubricating oil composition, as with a compression machine in a refrigerant circulation system such as a refrigerator and a room-air conditioner.

### Examples

[0058] Hereinafter, the present invention will be described in more detail by Examples. However, the present invention is not limited to Examples.

[0059] (Examples 1-1 and 1-2 and Comparative Examples 1-1 and 1-2)  
(Examples 2-1 to 2-4 and Comparative Example 2-1)  
(Examples 3-1 to 3-3 and Comparative Examples 3-1 and 3-2)  
<Preparation of Lubricating Oil Composition>

A lubricating oil composition was prepared by mixing a lubricating base oil and a wear inhibitor shown in Table 1, Table 2, and Table 3. Note that, a numerical value shown in Table 1, Table 2, and Table 3 indicates parts by mass.

[0060] The details of each component are as follows.

#### [Lubricating Base Oil]

Lubricating Base Oil 1: poly $\alpha$ -olefin (PAO, Product Name: Durasyn-164, manufactured by INEOS Group, Ltd., Kinetic Viscosity at 40°C: 17.5 mm<sup>2</sup>/s, Kinetic Viscosity at 100°C: 4.0 mm<sup>2</sup>/s)

Lubricating Base Oil 2: poly $\alpha$ -olefin (PAO, Product Name: Durasyn-168, manufactured by INEOS Group, Ltd., Kinetic Viscosity at 40°C: 46.0 mm<sup>2</sup>/s, Kinetic Viscosity at 100°C: 8.0 mm<sup>2</sup>/s)

Lubricating Base Oil 3: mineral oil-based hydrocarbon oil (API

1509, Base Oil Classification according to Appendix E: Group III, Kinetic Viscosity at 40°C: 20.3 mm<sup>2</sup>/s, Kinetic Viscosity at 100°C: 4.3 mm<sup>2</sup>/s, Viscosity Index: 121, Density at 15°C: 0.836 g/cm<sup>3</sup>)

5 Lubricating Base Oil 4: mineral oil-based hydrocarbon oil (API 1509, Base Oil Classification according to Appendix E: Group I, Kinetic Viscosity at 40°C: 3.4 mm<sup>2</sup>/s, Kinetic Viscosity at 100°C: 1.3 mm<sup>2</sup>/s, Viscosity Index: 84, Density at 15°C: 0.830 g/cm<sup>3</sup>)

[Wear Inhibitor]

10 Comparative Wear Inhibitor: N-oleoyl sarcosine (Product Name: Sarkosyl O, manufactured by BASF SE)

Wear Inhibitor 1-1: tricresyl phosphate (Product Name: TCP, manufactured by DAIHACHI CHEMICAL INDUSTRY CO., LTD., a first wear inhibitor)

15 Wear Inhibitor 1-2: dioleoyl phosphite (Product Name: JP-218-OR, manufactured by Johoku Chemical Co., Ltd., a first wear inhibitor)

Wear Inhibitor 1-3: zinc di-n-butyl phosphate (Content of Phosphorus: 13.2 mass%, Content of Sulfur: 0 mass%, Content of Zinc: 13 mass%, a first wear inhibitor)

20 Wear Inhibitor 2-1: sulfurized olefin (Product Name: GS-440L, manufactured by DIC Corporation, a second wear inhibitor)

Wear Inhibitor 3-1: zinc dialkyl dithiophosphate (ZnDTP, Product Name: HiTEC 653, manufactured by Afton Chemical Japan Corporation, a third wear inhibitor)

[0061] <Evaluation of Friction Properties>

25 The lubricating oil composition prepared as described above was subjected to a friction property test in the following condition by using a

mini traction machine (MTM) tester (manufactured by PCS Instruments Ltd.), and the average friction coefficient ( $\mu$ ) for the last 10 minutes was obtained. Note that, a steel ball obtained by preparing a commercially available steel ball of 1/2 inches, high carbon-chromium bearing steel (AISI52100), hardness of 800-920HV, and surface roughness  $< 0.02 \mu\text{m}$ , and by treating the commercially available steel ball with shot blast to adjust the surface to have arithmetic average roughness ( $R_a$ ) of  $0.5 \mu\text{m}$  was used as a ball. In addition, a PEEK sheet obtained by performing injection molding with respect to polyether ether ketone (PEEK, a super engineering plastic, KetaSpire (Registered Trademark) KT-820NT, manufactured by Solvay S. A.) to which a filler was not added to adjust the size to have a length of  $40 \text{ mm} \times$  a breadth of  $40 \text{ mm} \times$  a thickness of  $2 \text{ mm}$  was used as a disk (a PEEK disk). Results are shown in Table 1, Table 2, and Table 3. The friction properties are excellent as the friction coefficient decreases.

Oil Temperature:  $25^\circ\text{C}$

Load:  $50 \text{ N}$

Circumferential Velocity:  $0.5 \text{ m/s}$

Sliding Ratio:  $50\%$

Test Time:  $60 \text{ minutes}$

[0062] <Evaluation of Wear Properties>

A volume wear amount was obtained by measuring the depth of a wear mark on the disk after the friction property test described above. Results are shown in Table 1, Table 2, and Table 3. The wear properties are excellent as the volume wear amount decreases.

[0063] Table 1

|                                      | Comp.<br>Exam. 1-1 | Comp.<br>Exam. 1-2 | Exam. 1-1 | Exam. 1-2 |
|--------------------------------------|--------------------|--------------------|-----------|-----------|
| Lubricating base oil 1               | 100                | 99                 | 99        | 99        |
| Comp. wear inhibitor                 | -                  | 1                  | -         | -         |
| Wear inhibitor 1-1                   | -                  | -                  | 1         | -         |
| Wear inhibitor 3-1                   | -                  | -                  | -         | 1         |
| Friction coefficient ( $\mu$ )       | 0.074              | 0.111              | 0.060     | 0.064     |
| Volume wear amount ( $\text{mm}^3$ ) | 1.74               | 2.27               | 0.97      | 0.72      |

[0064] Table 2

|                                       | Comp.<br>Exam. 2-1 | Exam. 2-1 | Exam. 2-2 | Exam. 2-3 | Exam. 2-4 |
|---------------------------------------|--------------------|-----------|-----------|-----------|-----------|
| Lubricating base oil 2                | 100                | 99        | 99        | 99        | 99        |
| Wear inhibitor 1-2                    | -                  | 1         | -         | -         | -         |
| Wear inhibitor 1-3                    | -                  | -         | 1         | -         | -         |
| Wear inhibitor 2-1                    | -                  | -         | -         | 1         | -         |
| Wear inhibitor 3-1                    | -                  | -         | -         | -         | 1         |
| Friction coefficient ( $\mu$ )        | 0.080              | 0.073     | 0.062     | 0.063     | 0.066     |
| Volume wear amount (mm <sup>3</sup> ) | 2.30               | 2.26      | 0.90      | 1.44      | 0.78      |

[0065] Table 3

|                                      | Comp.<br>Exam. 3-1 | Comp.<br>Exam. 3-2 | Exam. 3-1 | Exam. 3-2 | Exam. 3-3 |
|--------------------------------------|--------------------|--------------------|-----------|-----------|-----------|
| Lubricating base oil 3               | 100                | -                  | 99        | 99        | -         |
| Lubricating base oil 4               | -                  | 100                | -         | -         | 99        |
| Wear inhibitor 2-1                   | -                  | -                  | 1         | -         | -         |
| Wear inhibitor 3-1                   | -                  | -                  | -         | 1         | 1         |
| Friction coefficient ( $\mu$ )       | 0.070              | 0.075              | 0.065     | 0.064     | 0.067     |
| Volume wear amount ( $\text{mm}^3$ ) | 1.70               | 2.02               | 0.82      | 0.76      | 0.80      |

[0066] (Comparative Examples 4-1 and 4-2)

<Preparation of Lubricating Oil Composition>

5 A lubricating oil composition was prepared by mixing a lubricating base oil and a wear inhibitor shown in Table 4. Note that, a numerical value shown in Table 4 indicates parts by mass. In addition, the details of each component are as described above.

[0067] <Evaluation of Friction Properties and Evaluation of wear Properties>

10 The lubricating oil composition prepared as described above was subjected to the evaluation of the friction properties and the evaluation of the wear properties as described above, except that the PEEK disk was changed to a steel disk (a standard steel disk, manufactured by PCS Instruments Ltd., Material: AISI52100). Results are shown in Table 4. For comparison, the data of Comparative Example 2-1 and Example 2-3  
15 is also shown.

[0068] Table 4

|                                       | Comp.<br>Exam. 4-1 | Comp.<br>Exam. 4-2 | Comp.<br>Exam. 2-1 | Exam. 2-3      |
|---------------------------------------|--------------------|--------------------|--------------------|----------------|
| Lubricating base oil 2                | 100                | 99                 | 100                | 99             |
| Wear inhibitor 2-1                    | -                  | 1                  | -                  | 1              |
| Material of ball                      | Steel              | Steel              | Steel              | Steel          |
| Material of disk                      | Steel              | Steel              | PEEK               | PEEK           |
| Friction coefficient ( $\mu$ )        | 0.087              | 0.101              | 0.080              | 0.063          |
| Volume wear amount (mm <sup>3</sup> ) | 0.075<br>(Steel)   | 0.126<br>(Steel)   | 2.30<br>(PEEK)     | 1.44<br>(PEEK) |

[0069] As shown in Table 1, Table 2, and Table 3, in Examples using a lubricating oil composition containing a specific wear inhibitor, it was possible to reduce the friction coefficient between the sliding members, and to reduce the volume wear amount, compared to Comparative Examples using only a lubricating base oil and Comparative Examples using a lubricating oil composition not containing the specific wear inhibitor. In addition, as shown in Table 4, in a case where the combination of the pair of sliding members was the steel ball and the steel disk, in Comparative Example 4-2 to which the specific wear inhibitor was added, the friction properties and the wear properties were degraded, compared to Comparative Example 4-1 to which the specific wear inhibitor was not added. On the other hand, in a case where the combination of the pair of sliding members was the steel ball and the PEEK disk, there was a difference in the absolute value of the volume wear amount according to the type of disk between Comparative Example 4-1 and Comparative Example 4-2, but in Example 2-3 to which the specific wear inhibitor was added, the friction properties and the wear properties were excellent, compared to Comparative Example 2-1 to which the specific wear inhibitor was not added. Accordingly, it was determined that an improvement in slidability according to the use of the specific wear inhibitor is an effect that is uniquely exhibited when at least one of the pair of sliding members is a member containing an engineering plastic. From the above, it was found that the lubrication method of the present invention is capable of improving the slidability in a case of using a resin material as a sliding member.

**CLAIMS**

1. A lubrication method of lubricating a pair of sliding members by using a lubricating oil composition,

wherein at least one of the pair of sliding members is a member containing an engineering plastic, and

the lubricating oil composition comprises a lubricating base oil, and at least one type of wear inhibitor selected from the group consisting of a wear inhibitor containing phosphorus but not sulfur as a constituent element, a wear inhibitor containing sulfur but not phosphorus as a constituent element, and a wear inhibitor containing phosphorus and sulfur as a constituent element.

2. The lubrication method according to claim 1,

wherein one of the pair of sliding members is a member containing an engineering plastic, and the other is a member containing an iron-based material.