US 20170327764A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2017/0327764 A1**

(43) **Pub. Date: Nov. 16, 2017**

NAGAKARI

(54) **LUBRICATING OIL COMPOSITION FOR SLIDING GLIDE SURFACE**

(71) Applicant: **SHELL OIL COMPANY**, HOUSTON, TX (US)

(72) Inventor: **Mitsuhiro NAGAKARI**, Tokyo (JP)

(21) Appl. No.: **15/533,802**

(22) PCT Filed: **Dec. 7, 2015**

(86) PCT No.: **PCT/EP2015/078788**

§ 371 (c)(1),
(2) Date: **Jun. 7, 2017**

(30) **Foreign Application Priority Data**

Dec. 9, 2014 (JP) 2014-249030

Publication Classification

(51) **Int. Cl.**

C10M 169/04	(2006.01)
C10M 101/04	(2006.01)
C10M 137/12	(2006.01)
C10M 141/10	(2006.01)
C10M 107/02	(2006.01)
C10M 129/40	(2006.01)

(52) **U.S. Cl.**

CPC ***C10M 169/04*** (2013.01); ***C10M 107/02*** (2013.01); ***C10M 129/40*** (2013.01); ***C10M 137/12*** (2013.01); ***C10M 141/10*** (2013.01); ***C10M 101/04*** (2013.01); *C10M 2205/0206* (2013.01); *C10M 2207/122* (2013.01); *C10M 2207/126* (2013.01); *C10M 2223/06* (2013.01); *C10N 2240/06* (2013.01); *C10M 2203/003* (2013.01)

(57) **ABSTRACT**

A lubricating oil composition for a sliding guide surface, which exhibits excellent low friction properties and extreme pressure properties so as to enable high precision machining in a machine tool, is disclosed.

LUBRICATING OIL COMPOSITION FOR SLIDING GLIDE SURFACE

FIELD OF THE INVENTION

[0001] The present invention relates to a lubricating oil composition which is suitable for lubricating a sliding guide surface of a machine tool or the like.

BACKGROUND OF THE INVENTION

[0002] In order to carry out high precision machining by means of a machine tool, it is essential for the positioning accuracy of a feed shaft of the machine tool to be excellent, with micron level precision being required in some cases. However, lubricating oils are used because positioning accuracy can deteriorate due to friction resistance produced on a guide surface of a machine tool having a sliding guide surface, and it is necessary for a lubricating oil used on this guide surface to exhibit low friction.

[0003] In addition, lubricating oils used in machine tools can also be used to lubricate gears and the like in addition to guide surfaces as described above, and in such cases load bearing properties are also required as an important feature.

[0004] Therefore, because smooth movement and high precision are required of guide surfaces, a variety of friction-reducing agents are blended in lubricating oils used on guide surfaces in order to reduce friction. For example, JP 11-505283 discloses that attempts have been made to achieve low friction properties and good sliding properties by using combinations of acidic esters of phosphoric acid and phosphoric acid esters.

SUMMARY OF INVENTION

[0005] Conventional lubricating oil compositions have yet to achieve satisfactory lubricating properties for machine tools for which high precision machining is required, and an objective of the present invention, which has been devised with these circumstances in mind, is to obtain a lubricating oil composition having further improved frictional properties and extreme pressure properties.

[0006] As a result of various investigations and research carried out with the aim of reducing friction and achieving good extreme pressure properties, as described above, it was found that in cases where a combination of a phosphonic acid ester and a fatty acid was used, a lower coefficient of friction and higher load bearing properties could be achieved than in cases where either of these additives was used in isolation, and the present invention was completed on the basis of these findings.

[0007] The present invention provides a lubricating oil composition for a sliding guide surface, which contains any of a base oil of group I, a base oil of group II, a base oil of group III or a base oil of group IV in the API (American Petroleum Institute) base oil categories, or a mixture thereof, as a base oil, and which is obtained by adding, to this base oil, a combination of a phosphonate (phosphonic acid ester) and a middle or higher fatty acid.

[0008] In addition, it is more preferable for the base oil to be a group III base oil that is a highly refined mineral oil or a base oil that is a group IV synthetic oil in the API base oil categories, or a mixture thereof.

[0009] The lubricating oil composition of the present invention can exhibit excellent frictional properties and load bearing properties on a sliding guide surface of a machine tool or the like, and can be effectively used as a lubricating oil composition for a sliding guide surface.

DETAILED DESCRIPTION OF THE INVENTION

[0010] A base oil of group I to group IV in the API base oil categories, or a mixture thereof, is used in the base oil of the grease of the present invention. An example of a group I base oil is a paraffin-based mineral oil obtained by subjecting a lubricating oil distillate, which is obtained by subjecting crude oil to atmospheric distillation, to an appropriate combination of refining procedures, such as solvent refining, hydrorefining and dewaxing.

[0011] The viscosity index is suitably from 80 to 120, and preferably from 95 to 110. The kinematic viscosity at 40° C. is preferably from 2 to 680mm^2/s, and more preferably from 8 to 220mm^2/s. In addition, the total sulfur content is suitably greater than 300ppm and less than 700 ppm, and preferably less than 500ppm. The total nitrogen content is suitably less than 50ppm, and preferably less than 25ppm. Furthermore, the aniline point should be from 80 to 150° C., and preferably from 90 to 120° C.

[0012] An example of a group II base oil is a paraffin-based mineral oil obtained by subjecting a lubricating oil distillate, which is obtained by subjecting crude oil to atmospheric distillation, to an appropriate combination of refining procedures, such as hydrocracking and dewaxing.

[0013] The viscosity of these base oils is not particularly limited, but the viscosity index is suitably from 80 to less than 120, and preferably from 100 to less than 120. The kinematic viscosity at 40° C. is preferably from 2 to 680 mm^2/s, and more preferably from 8 to 220 mm^2/s.

[0014] In addition, the total sulfur content is suitably no greater than 300ppm, preferably no greater than 200 ppm, and more preferably no greater than 10 ppm. The total nitrogen content is suitably less than 10 ppm, and preferably less than 1 ppm. Furthermore, the aniline point is suitably from 80 to 150° C., and preferably from 100 to 135° C.

[0015] In addition, a group II base oil that has been refined using a hydrorefining process such as that used by Gulf Oil suitably has a total sulfur content of less than 10 ppm and an aromatics content of 5% or less, and can be advantageously used in the present invention.

[0016] Examples of group III base oils include a paraffin-based mineral oil produced by subjecting a lubricating oil distillate, which is obtained by subjecting crude oil to atmospheric distillation, to a high degree of hydrorefining, a base oil obtained by refining a wax, which is produced in a dewaxing process, using an isodewax process in which conversion and dewaxing are carried out, or a base oil that has been refined using the wax isomerization process used by Mobil Oil. The viscosity of these group III base oils is not particularly limited, but the viscosity index should be from 120 to 180, and preferably from 130 to 150. The kinematic viscosity at 40° C. is preferably from 2 to 680 mm^2/s, and more preferably from 8 to 220 mm^2/s. In addition, the total sulfur content is suitably 300ppm or less, and preferably 10 ppm or less. The total nitrogen content is suitably 10 ppm or less, and preferably 1 ppm or less. Furthermore, the aniline point is suitably from 80 to 150° C., and preferably from 110 to 135° C.

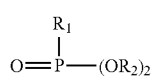
[0017] In addition, as a base oil belonging to group III, a GTL (gas to liquid) base oil synthesized by the Fischer-Tropsch process, which is a technique for converting natural gas into liquid fuel, has a significantly lower sulfur content and aromatics content and a significantly higher paraffin proportion than a mineral oil-based base oil refined from crude oil, and therefore exhibits excellent oxidation stability and extremely low evaporative losses, and can be advantageously used as the base oil in the present invention.

[0018] The viscosity properties of this GTL base oil are not particularly limited, but the viscosity index is generally from 130 to 180, and more preferably from 140 to 175. In addition, the kinematic viscosity at 40° C. is suitably from 2 to 680 mm^2/s, and more preferably from 5 to 120 mm^2/s. In addition, the total sulfur content is generally less than 10 ppm, and the total nitrogen content is generally less than 1 ppm. An example of this type of GTL base oil product is SHELL XHVI™.

[0019] Polyolefins are an example of a base oil belonging to group IV, and these include polymers of a variety of olefins, and hydrogenated products thereof. Any type of olefin can be used, but examples thereof include ethylene, propylene, butene and α-olefins having 5 or more carbon atoms. When producing polyolefins, it is possible to use a single olefin in isolation or a combination of two or more types thereof. Particularly preferred are polyolefins known as poly-α-olefins (PAO).

[0020] The viscosity of these polyolefins is not particularly limited, but the kinematic viscosity at 40° C. is preferably from 2 to 680 mm^2/s, and more preferably from 8 to 220 mm^2/s.

[0021] The phosphonate mentioned above is represented by formula 1 below:



(1)

[0022] In formula 1 above, R_1 is a saturated or unsaturated alkyl group, and has 12-22 carbon atoms, and preferably 12-18 carbon atoms. R_2 is a saturated or unsaturated alkyl group having 1-18 carbon atoms. These alkyl groups are often linear, but may be branched.

[0023] Examples of this type of phosphonate include dimethyldodecyl phosphonate, dimethyltridecyl phosphonate, dimethyltetradecyl phosphonate, dimethylpentadecyl phosphonate, dimethylhexadecyl phosphonate, dimethylheptadecyl phosphonate, dimethyloctadecyl phosphonate, dimethylnonadecyl phosphonate, dimethyleicosyl phosphonate, tridodecyl phosphonate, tritridecyl phosphonate, tritetradecyl phosphonate, tripentadecyl phosphonate, trihexadecyl phosphonate, triheptadecyl phosphonate, trioctadecyl phosphonate (tristearyl phosphite: tautomer) and trioleyl phosphonate.

[0024] This type of phosphonate is suitably used at a quantity of the order of not less than 0.2 mass % but less than 2 mass %, and preferably not less than 0.5 mass % and not more than 1.5 mass %, relative to the overall quantity of the lubricating oil composition.

[0025] The fatty acid mentioned above is represented by formula 2 below.

$$R_3COOH \qquad (2)$$

In formula 2 above, R_3 is a saturated or unsaturated alkyl group having 7-17 carbon atoms.

[0026] Examples of this type of fatty acid include caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, isostearic acid, oleic acid, linoleic acid and linolenic acid.

[0027] This type of fatty acid is suitably used at a quantity of the order of not less than 0.03 mass % but less than 1 mass %, and preferably not less than 0.1 mass % and not more than 0.7 mass %, relative to the overall quantity of the lubricating oil composition.

[0028] Metal deactivators, anti-wear agents, and the like, can also be added to this lubricating oil composition. Examples of metal deactivators include thiadiazole derivatives, for example 2,5-bis(alkyldithio)-1,3,4-thiadiazole compounds such as 2,5-bis(heptyldithio)-1,3,4-thiadiazole, 2,5-bis(nonyldithio)-1,3,4-thiadiazole, 2,5-bis(dodecyldithio)-1,3,4-thiadiazole and 2,5-bis(octadecyldithio)-1,3,4-thiadiazole; 2,5-bis(N,N-dialkyldithiocarbamyl)-1,3,4-thiadiazole compounds such as 2,5-bis(N,N-diethyldithiocarbamyl)-1,3,4-thiadiazole, 2,5-bis(N,N-dibutyldithiocarbamyl)-1,3,4-thiadiazole and 2,5-bis(N,N-dioctyldithiocarbamyl)-1,3,4-thiadiazole; and 2-N,N-dialkyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole compounds such as 2-N,N-dibutyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole and 2-N,N-dioctyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole. In some cases, it is possible to use a benzotriazole or benzotriazole derivative, a benzimidazole or benzimidazole derivative, an imidazole or imidazole derivative, a benzothiazole or benzothiazole derivative, a benzoxazole derivative, a triazole derivative, or the like. It is possible to use one or more of these metal deactivators at a quantity of approximately 0.01-0.5 mass % in the lubricating oil composition.

[0029] Examples of the anti-wear agent include diisobutyl disulfide, diisobutyl trisulfide, di-t-butyl trisulfide, dioctyl trisulfide, di-t-nonyl trisulfide, di-t-benzyl trisulfide, and other polysulfides. It is also possible to use a sulfurized olefin, a sulfurized oil or fat, or the like. It is possible to use one or more of these sulfur-based anti-wear agents at a quantity of from approximately 0.1 to 3 mass % in the lubricating oil composition.

[0030] In addition, these metal deactivators and anti-wear agents can be used in isolation or in appropriate combinations thereof, and in cases where these are used in combination, a low coefficient of friction can be achieved, better abrasion resistance and extreme pressure properties can be achieved, and a sliding guide surface can be effectively lubricated under harsh conditions.

[0031] If necessary, antioxidants such as amine-based and phenol-based antioxidants, corrosion inhibitors, structure stabilizers, viscosity modifiers, dispersing agents, pour point depressants, anti-foaming agents and other known additives can be blended as appropriate in the lubricating oil composition of the present invention.

[0032] The viscosity grade of the lubricating oil composition for a sliding guide surface described above should be VG22 to VG220, and preferably VG32 to VG68, according to ISO viscosity grades.

[0033] The lubricating oil composition for a sliding guide surface of the present invention will now be described in specific terms through working examples and comparative examples, but the present invention is in no way limited to these examples.

EXAMPLES

[0034] The following materials were prepared in order to produce the working examples and comparative examples.

Base Oils

[0035] Base oil 1: GTL (gas to liquid) base oil belonging to group III (properties: kinematic viscosity at 100° C.: 7.579 mm^2/s, kinematic viscosity at 40° C.: 43.69 mm^2/s, viscosity index (VI): 141, density at 15° C.: 0.8284) (Shell XHVI-8 manufactured by Royal Dutch Shell)

[0036] Base oil 2: Refined mineral oil belonging to group III (properties: kinematic viscosity at 100° C.: 7.545 mm^2/s, kinematic viscosity at 40° C.: 45.50 mm^2/s, viscosity index (VI): 132, density at 15° C.: 0.8453) (Yu-Base 8 manufactured by SK Innovation)

[0037] Base oil 3: PAO (poly-α-olefin) belonging to group IV (properties: kinematic viscosity at 100° C.: 7.741 mm^2/s, kinematic viscosity at 40° C.: 46.25 mm^2/s, viscosity index (VI): 136, density at 15° C.: 0.8322) (Durasyn 168 manufactured by Ineos Oligomers)

[0038] Base oil 4: Refined mineral oil belonging to group II (properties: kinematic viscosity at 100° C.: 5.352 mm^2/s, kinematic viscosity at 40° C.: 31.10 mm^2/s, viscosity index (VI): 105, density at 15° C.: 0.8627)

[0039] Base oil 5: Refined mineral oil belonging to group II (properties: kinematic viscosity at 100° C.: 9.490 mm^2/s, kinematic viscosity at 40° C.: 73.66 mm^2/s, viscosity index (VI): 106, density at 15° C.: 0.8683)

[0040] Base oil 6: Refined mineral oil belonging to group I (properties: kinematic viscosity at 100° C.: 4.628 mm^2/s, kinematic viscosity at 40° C.: 24.32 mm^2/s, viscosity index (VI): 106, density at 15° C.: 0.8625)

[0041] Base oil 7: Refined mineral oil belonging to group I (properties: kinematic viscosity at 100° C.: 7.446 mm^2/s, kinematic viscosity at 40° C.: 51.37 mm^2/s, viscosity index (VI): 106, density at 15° C.: 0.8736)

Additives

[0042] Additive 1-1: Dimethyloctadecyl phosphonate

[0043] Additive 1-2: Tridodecyl phosphonate

[0044] Additive 1-3: Tristearyl phosphite

[0045] Additive 2-1: Caprylic acid

[0046] Additive 2-2: Lauric acid

[0047] Additive 2-3: Stearic acid

[0048] Additive 2-4: Oleic acid

[0049] Additive 3: Diethyl benzylphosphonate

[0050] Additive 4: Behenic acid

[0051] Additive 5: Thiadiazole

[0052] Additive 6: Di-t-dodecyl trisulfide

Working Examples 1-16 and Comparative Examples 1-12

[0053] Lubricating oil compositions for a sliding guide surface of Working Examples 1-16 and Comparative Examples 1-12 were prepared using the materials mentioned above according to the compositions shown in Tables 1-3 below. The blending quantities of the components are shown as mass %.

Tests

Coefficient of Friction: Pendulum Type Coefficient of Friction Test

[0054] The coefficients of friction of the lubricating oil compositions of Working Examples 1-16 and Comparative Examples 1-12 were measured using a Soda type pendulum type oiliness tester manufactured by Shinko Engineering Co., Ltd. In this test, a test oil was applied to a wear part that was the support point of a pendulum, the pendulum was made to swing, and the coefficient of friction was determined from the attenuation of the swing. The test was carried out at room temperature (25° C.)

[0055] Evaluation of the test was carried out according to the following criteria:

[0056] A coefficient of friction of 0.110 or less was deemed to be ○ (pass).

[0057] A coefficient of friction of greater than 0.110 was deemed to be × (fail).

Flash Point

[0058] The flash points of samples of Working Examples 1-16 and Comparative Examples 1-12 were measured five times in accordance with JIS K2265-4 using a Cleveland open cup automatic flash point measurement apparatus, and the average value was determined by rounding off to 1 digit after the decimal point. The thermometer used was a no. 32 thermometer specified in JIS B7410 (COC).

[0059] Evaluation of the test was carried out according to the following criteria:

[0060] A flash point of 220° C. or higher was deemed to be ○ (pass).

[0061] A flash point of less than 220° C. was deemed to be × (fail).

Load Bearing Properties Test: Shell Four-Ball EP Test

[0062] Working Examples 1 and 12 and Comparative Examples 5 and 6 were subjected to a load bearing test in accordance with ASTM D2783.

[0063] Conditions: Speed of rotation: 1760±40 rpm

[0064] Duration: 10 seconds

[0065] Temperature: room temperature

[0066] Test items: ISL (Initial Seizure Load, units kgf) and WL (Weld Load, units kgf).

[0067] Test method: numerical values were determined by applying loads of 50 kgf, 63 kgf, 80 kgf, 100 kgf, 126 kgf, 160 kgf, 200 kgf, 250 kgf and 315 kgf up to the WL.

[0068] Evaluation of the ISL was carried out according to the following criteria:

[0069] 80 kgf or more was deemed to be ○ (pass).

[0070] Less than 80 kgf was deemed to be × (fail).

[0071] In addition, evaluation of the WL was carried out according to the following criteria:

[0072] 126 kgf or more was deemed to be ○ (pass).

[0073] Less than 126 kgf was deemed to be × (fail).

Abrasion Resistance Test: Shell Four-Ball Wear Test

[0074] The test equipment and test methods were such that a load of 40 kgf was applied in accordance with ASTM D4172, the oil temperature was 75° C., the tester was rotated at 1200 rpm for 1 hour, and the diameter of an abrasion mark occurring at the point of contact was measured. Working Examples 1 and 12 and Comparative Examples 5 and 6 were subjected to this test.

[0075] Evaluation of the test was carried out according to the following criteria:

[0076] An abrasion mark diameter of 0.50 mm or less was deemed to be ○ (pass).

[0077] An abrasion mark diameter of greater than 0.50 mm was deemed to be × (fail).

Storage Stability

[0078] The lubricating oil compositions of Working Examples 1-16 and Comparative Examples 1-12 were allowed to stand for 1 day (24 hours) at 25° C., after which the presence/absence of cloudiness or precipitation was determined visually.

[0079] Examples in which cloudiness and precipitation had not occurred were deemed to be ○ (pass).

[0080] Examples in which cloudiness or precipitation had occurred are as shown in the tables.

[0081] With regard to storage stability, examples in which cloudiness or precipitation had occurred were unsuitable as lubricating oil compositions for sliding guide surfaces, and were therefore not subjected to the other tests described above.

Test Results

[0082] The test results for the working examples and comparative examples are shown in Tables 1-3.

TABLE 1

	Working Example 1	Working Example 2	Working Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7
Base oil 1	98.75	98.75		99.0	99.0	99.0		99.75	99.88	97.0
Base oil 2			98.75				99.0			
Base oil 3										
Base oil 4										
Base oil 5										
Base oil 6										
Base oil 7										
Additive 1-1	1.0			1.0					0.1	2.0
Additive 1-2						1.0	1.0			
Additive 1-3		1.0	1.0		1.0					
Additive 3										
Additive 2-1										
Additive 2-2										
Additive 2-3	0.25	0.25	0.25					0.25	0.02	1.00
Additive 2-4										
Additive 4										
Additive 5										
Additive 6										
Coefficient of friction	0.093	0.091	0.089	0.114	0.113	0.116	0.135	0.092	0.107	
Flash point (° C.)	270	260	258	264	264	268	246	268	266	
Four-ball EP: ISL	80							63	50	
Four-ball EP: WL	126							126	100	
Four-ball wear	0.41							0.73	0.81	
Storage stability	○	○	○	○	○	○	○	○	○	Cloudy

TABLE 2

	Working Example 4	Working Example 5	Working Example 6	Working Example 7	Working Example 8	Working Example 9	Working Example 10	Comparative Example 8	Comparative Example 9	Comparative Example 10
Base oil 1	98.82	98.3	98.77	98.7	98.7	98.7		98.65	97.45	99.95
Base oil 2							98.7			
Base oil 3										
Base oil 4										
Base oil 5										
Base oil 6										
Base oil 7										
Additive 1-1	1.0	1.0	1.0	1.0	1.0			1.0	1.0	
Additive 1-2						1.0	1.0			
Additive 1-3										
Additive 3										
Additive 2-1	0.13	0.65								
Additive 2-2			0.18							
Additive 2-3				0.25		0.25	0.25			

TABLE 2-continued

	Working Example 4	Working Example 5	Working Example 6	Working Example 7	Working Example 8	Working Example 9	Working Example 10	Comparative Example 8	Comparative Example 9	Comparative Example 10
Additive 2-4					0.25					
Additive 4								0.3	1.5	
Additive 5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Additive 6										
Coefficient of friction	0.100	0.105	0.097	0.092	0.096	0.099	0.097			0.146
Flash point (° C.)	272	272	268	272	264	268	246			272
Four-ball EP: ISL										
Four-ball EP: WL										
Four-ball wear										
Storage stability	○	○	○	○	○	○	○	Precipitation	Precipitation	○

TABLE 3

	Working Example 11	Working Example 12	Working Example 13	Working Example 14	Working Example 15	Working Example 16	Comparative Example 11	Comparative Example 12
Base oil 1	97.75	97.7					99	98.1
Base oil 2				97.7				
Base oil 3			97.7					
Base oil 4					62			
Base oil 5					35.7			
Base oil 6						19.54		
Base oil 7						78.16		
Additive 1-1	1.0	1.0	1.0	1.0	1.0	1.0		
Additive 1-2								
Additive 1-3								
Additive 3								0.6
Additive 2-1								
Additive 2-2								
Additive 2-3	0.25	0.25	0.25	0.25	0.25			0.25
Additive 2-4								
Additive 4								
Additive 5		0.05	0.05	0.05	0.05	0.05		0.05
Additive 6	1	1	1	1	1	1	1	1
Coefficient of friction	0.092	0.094	0.092	0.093	0.092	0.092	0.143	0.122
Flash point (° C.)	266	260	258	242	226	224	250	214
Four-ball EP: ISL		160						
Four-ball EP: WL		200						
Four-ball wear		0.40						
Storage stability	○	○	○	○	○	○	○	○

[0083] As shown in Table 1, the composition of Working Example 1, which contained base oil 1 and additives 1-1 and 2-3, had a low coefficient of friction of 0.093 and a high flash point of 270° C., and was found to be excellent as a lubricating oil composition for a sliding guide surface. However, the composition of Comparative Example 1, which did not contain additive 2-3, passed in terms of flash point, but was found to be unsuitable due to having a high coefficient of friction of 0.114.

[0084] Similarly, comparing Working Example 2 and Comparative Example 2, Working Example 2 was suitable, whereas Comparative Example 2, which differed from Working Example 2 by not containing additive 2-3, was found to be unsuitable. In addition, Working Example 3, which was obtained by replacing base oil 1 in Working Example 2 with base oil 2, was good.

[0085] In addition, compositions which contained additive 1-2 but did not contain additive 2, such as Comparative Examples 3 and 4, could not achieve good results. Comparative Example 5 differed from Working Example 1 by not containing additive 1-1, but passed in terms of coefficient of friction and flash point. However, Comparative Example 5 exhibited the same WL as Working Example 1 of 126 kgf in the Shell four-ball EP test, but had a lower ISL (63 kgf) than that of Working Example 1 (80 kgf) and had a worse abrasion mark diameter of 0.73 than that of Working

Example 1 (0.41) in the Shell four-ball wear test, and was found to be unsuitable.

[0086] Comparative Example 6 contained the same components as Working Example 1, but contained lower quantities of additive 1 and additive 2, and failed in terms of coefficient of friction, ISL and WL in the Shell four-ball EP test and abrasion mark diameter in the Shell four-ball wear test, and was significantly inferior to Working Example 1.

[0087] Comparative Example 7 contained the same components as Working Example 1, but contained higher quantities of additive 1 and additive 2 and exhibited cloudiness in the storage stability test, and was unsuitable. Because cloudiness occurred, as mentioned above, the other tests were not carried out.

[0088] As shown in Table 2, the compositions of Working Examples 4-8 all contained base oil 1 and additive 1-1, all contained additive 5, and varied in terms of the type and content of additive 2, but all passed in terms of coefficient of friction and flash point, and were found to be suitable.

[0089] Working Example 9 differed from Working Example 7 by containing additive 1-2 instead of additive 1-1, and Working Example 10 differed from Working Example 9 by containing base oil 2 instead of base oil 1, but Working Examples 9 and 10 passed in terms of coefficient of friction and flash point, and were found to be suitable.

[0090] Comparative Example 8 differed from Working Examples 4-8 by containing 0.3 mass % of additive 4 (behenic acid) instead of additive 2, and Comparative Example 9 differed from Working Examples 4-8 by containing 1.5 mass % of additive 4 (behenic acid) instead of additive 2, but Comparative Examples 8 and 9 underwent precipitation in the storage stability test, and were therefore undesirable. In addition, because precipitation occurred, the other tests were not carried out.

[0091] Comparative Example 10 contained additive 5 in base oil 1, but did not contain additive 1 or additive 2, and passed in terms of flash point, but was found to be unsuitable due to exhibiting an extremely high coefficient of friction of 0.146.

[0092] As shown in Table 3, Working Example 11 was obtained by adding additive 6 to the composition of Working Example 1, and passed in terms of coefficient of friction and flash point.

[0093] Working Example 12 was obtained by adding additive 5 and additive 6 to the composition of Working Example 1, and passed in terms of coefficient of friction and flash point, and exhibited a similar abrasion mark diameter to Working Example 1 in a Shell four-ball wear test, but exhibited higher values for ISL and WL in a Shell four-ball EP test, and was therefore found to be more preferable in cases where high extreme pressure properties are required.

[0094] Working Examples 13-16 were obtained by replacing base oil 1 used in Working Example 12 with other base oils, and all passed in terms of coefficient of friction, and Working Examples 15 and 16 were slightly inferior in terms of flash point, but still passed.

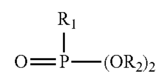
[0095] Comparative Example 11 differed from Working Example 11 by not containing additive 1 or additive 2, and passed in terms of flash point, but was unsuitable due to exhibiting a high coefficient of friction, like Comparative Example 10.

[0096] Comparative Example 12 differed from Working Example 12 by containing additive 3, which is a phosphonic acid ester having a benzene ring, instead of additive 1-1, and failed in terms of coefficient of friction and flash point, and was found to be unsuitable.

1. A lubricating oil composition for a sliding guide surface comprising:

a base oil that is a base oil of group Ito group IV in the API base oil categories or a mixture thereof,

a phosphonate represented by formula 1



(1)

wherein R_1 denotes a saturated or unsaturated alkyl group having 12-22 carbon atoms, and R_2 denotes a saturated or unsaturated alkyl group having 1-18 carbon atoms, and

a fatty acid represented by formula 2

$$R_3COOH \quad (2)$$

wherein R3 denotes a saturated or unsaturated alkyl group having 7-17 carbon atoms.

2. A lubricating oil composition for a sliding guide surface according to claim **1**, wherein the phosphonate is present in a quantity of not less than 0.2 mass % but less than 2 mass % relative to the overall quantity of the lubricating oil composition, and the fatty acid is is present in a quantity of not less than 0.03 mass % but less than 1 mass % relative to the overall quantity of the lubricating oil composition.

3. A lubricating oil composition for a sliding guide surface according to claim **1**, wherein the base oil is a base oil belonging to group III and/or a base oil belonging to group IV in the API base oil categories.

4. A lubricating oil composition for a sliding guide surface according to claim **1**, which further comprises an anti-wear agent and/or a metal deactivator.

5. (canceled)

6. A lubricating oil composition for a sliding guide surface according to claim **1**, wherein the fatty acid is present in a quantity of not less than 0.1 mass % and not more than 0.7 mass % relative to the overall quantity of the lubricating oil composition.

7. A lubricating oil composition for a sliding guide surface according to claim **1**, wherein the phosphonate comprises one or more phosphonates selected from the group consisting of dimethyldodecyl phosphonate, dimethyltridecyl phosphonate, dimethyltetradecyl phosphonate, dimethylpentadecyl phosphonate, dimethylhexadecyl phosphonate, dimethylheptadecyl phosphonate, dimethyloctadecyl phosphonate, dimethylnonadecyl phosphonate, dimethyleicosyl phosphonate, tridodecyl phosphonate, tritridecyl phosphonate, tritetradecyl phosphonate, tripentadecyl phosphonate, trihexadecyl phosphonate, triheptadecyl phosphonate, trioctadecyl phosphonate (tristearyl phosphite: tautomer) and trioleyl phosphonate.

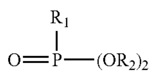
8. A lubricating oil composition for a sliding guide surface according to claim **1**, wherein the fatty acid comprises one or more more fatty acids selected from the group consisting of caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, isostearic acid, oleic acid, linoleic acid and linolenic acid.

9. A method comprising:

applying a lubricating oil composition to a sliding guide surface of a machine tool, wherein the lubricating oil composition comprises:

a base oil that is a base oil of group Ito group IV in the API base oil categories or a mixture thereof,

a phosphonate represented by formula 1



(1)

wherein R_1 denotes a saturated or unsaturated alkyl group having 12-22 carbon atoms, and R2 denotes a saturated or unsaturated alkyl group having 1-18 carbon atoms, and

a fatty acid represented by formula 2

$$R_3COOH \quad (2)$$

wherein R3 denotes a saturated or unsaturated alkyl group having 7-17 carbon atoms.

10. A method according to claim **9**, wherein the phosphonate in the lubricating oil composition is present in a quantity of not less than 0.2 mass % but less than 2 mass % relative to the overall quantity of the lubricating oil composition, and the fatty acid is is present in a quantity of not less than 0.03 mass % but less than 1 mass % relative to the overall quantity of the lubricating oil composition.

11. A method according to claim **9**, wherein the base oil is a base oil belonging to group III and/or a base oil belonging to group IV in the API base oil categories.

12. A method according to claim **9**, wherein the lubricating oil composition further comprises an anti-wear agent and/or a metal deactivator.

13. A method according to claim **9**, wherein the fatty acid in the lubricating oil composition is present in a quantity of not less than 0.1 mass % and not more than 0.7 mass % relative to the overall quantity of the lubricating oil composition.

14. A method according to claim **9**, wherein the phosphonate in the lubricating oil composition comprises one or more phosphonates selected from the group consisting of dimethyldodecyl phosphonate, dimethyltridecyl phosphonate, dimethyltetradecyl phosphonate, dimethylpentadecyl phosphonate, dimethylhexadecyl phosphonate, dimethylheptadecyl phosphonate, dimethyloctadecyl phosphonate, dimethylnonadecyl phosphonate, dimethyleicosyl phosphonate, tridodecyl phosphonate, tritridecyl phosphonate, tritetradecyl phosphonate, tripentadecyl phosphonate, trihexadecyl phosphonate, triheptadecyl phosphonate, trioctadecyl phosphonate (tristearyl phosphite: tautomer) and trioleyl phosphonate.

15. A method according to claim **9**, wherein the fatty acid in the lubricating oil composition comprises one or more more fatty acids selected from the group consisting of caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, isostearic acid, oleic acid, linoleic acid and linolenic acid.

* * * * *