US 20140142006A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2014/0142006 A1

(43) Pub. Date: May 22, 2014

Ichihashi et al.

(54) **LUBRICATING OIL COMPOSITION AND MECHANICAL APPARATUS**

(75) Inventors: **Toshihiko Ichihashi**, Ichihara-shi (JP); **Masato Yokomizo**, Ichihara-shi (JP); **Hiroshi Shirasawa**, Ichihara-shi (JP); **Toshiki Ikeda**, Ichihara-shi (JP)

(73) Assignee: **EDEMITSU KOSAN CO., LTD.**, Chiyoda-ku, Tokyo (JP)

(21) Appl. No.: **14/232,144**

(22) PCT Filed: **Jul. 11, 2012**

(86) PCT No.: **PCT/JP12/67668**

§ 371 (c)(1), (2), (4) Date: **Jan. 10, 2014**

(30) **Foreign Application Priority Data**

Jul. 11, 2011 (JP) 2011-153157

Publication Classification

(51) **Int. Cl.**
C10M 107/50 (2006.01)

(52) **U.S. Cl.**
CPC *C10M 107/50* (2013.01)
USPC **508/107**; 508/215; 508/212; 508/209; 508/211

(57) **ABSTRACT**

A lubricating oil composition contains: (A) organopolysiloxane; and (B) at least one of a sulfur compound, a phosphorus compound and a zinc compound, the lubricating oil composition having a kinematic viscosity not less than 1 mm^2/s and less than 40.0 mm^2/s at 100 degrees C. The lubricating oil composition is favorably usable in mechanical devices such as a hydraulic device, a stationary gear, an automobile transmission, a motor/battery cooling device and a joint.

LUBRICATING OIL COMPOSITION AND MECHANICAL APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a lubricating oil composition containing organopolysiloxane as a base stock and a mechanical device using the same.

BACKGROUND ART

[0002] Using a lubricating oil with a viscosity considerably variable depending on temperature in a hydraulic device or a transmission hinders a smooth operation of the device, resulting in loss of operational energy. In particular, for, for instance, a wind power generator built in a cold region, an accelerating/decelerating device or a hydraulic device used in a region that undergoes extreme temperature changes, an automatic transmission or a continuously variable transmission for an automobile intended to travel from a very cold region to an extremely hot region, and a cooling device, a used lubricating oil desirably has a viscosity less variable depending on temperature.

[0003] In connection with the above, a viscosity index (VI) is used as an index showing the temperature dependence of the viscosity of a lubricating oil. A typical viscosity index of a mineral oil is approximately 90 to 100. However, a desirable viscosity is at least 150 to 200, approximately, so that when a mineral oil is used as a base stock, a polymer compound (e.g., polymethacrylate), which is referred to as a viscosity index improver, is further blended to improve the viscosity index to 150 to 200, approximately. However, even when a lubricating oil has a viscosity index of 200, a viscosity of the lubricating oil at minus 20 degrees C. is approximately 100 times as large as a viscosity at 100 degrees C. and a viscosity at minus 40 degrees C. is more than 1000 times. Thus, the smooth operation of a device is hindered at a low temperature to considerably waste the operational energy. In view of the above, the temperature dependence of the viscosity of a lubricating oil is preferably as small as possible, so that polyalphaolefin or the like has been practically used as a base stock with a high viscosity index in place of a mineral oil in, for instance, a mechanical device required to smoothly operate at a low temperature. However, since the viscosity of hydrocarbon contained in a mineral oil or polyalphaolefin characteristically inevitably increases at a low temperature, a base stock with a higher viscosity index is required.

[0004] A silicone oil (organopolysiloxane), which is conventionally known as a compound with a low viscosity-temperature dependence, is used in special applications such as a gauge oil for an aircraft or a railcar for which variation in viscosity depending on temperature should be a problem. In view of the above, it has been considered to use a silicone oil as a base stock of a lubricating oil. For instance, it has been suggested to blend a silicone oil with an extreme pressure agent to be used as an impregnating oil for an oil-impregnated bearing (see Patent Literature 1). Further, an example of using a silicone oil with a high viscosity (a kinematic viscosity of 2000 mm^2/s or more at 100 degrees C.) as a viscous coupler has been disclosed (see Patent Literatures 2 and 3). Further, an example of using a silicone oil as a lubricating oil for a bumper has been disclosed (see Patent Literature 4).

CITATION LIST

Patent Literatures

[0005] Patent Literature 1: JP-A-2004-331895
[0006] Patent Literature 2: Japanese Patent No. 2579806
[0007] Patent Literature 3: JP-A-7-278584
[0008] Patent Literature 4: JP-A-2006-143926

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0009] However, while the viscosity of a silicone oil is less variable depending on temperature, the metal-metal lubricity thereof related to extreme pressure property is low, so that the use of a silicone oil as a lubricating oil is quite difficult. In Patent Literature 1, it has been suggested to add an extreme pressure agent to a lubricating oil and use it as an impregnating oil for an oil-impregnated bearing having a viscosity in an extremely high region, specifically, of 40 mm^2/s or more. However, the lubricity of even such a lubricating oil is still insufficient. Lubricating oils as suggested in Patent Literatures 2 to 4 are intended to be used only for a device that is hardly required to exhibit load bearing.

[0010] In other words, an example of using a lubricating oil that contains a silicone oil as a base stock for a typical hydraulic oil or gear oil or for a transmission that is required to exhibit a high load bearing (i.e., wear resistance) has not been suggested.

[0011] An object of the invention is to provide a lubricating oil composition with an excellent lubricity and a viscosity having an extremely small temperature dependence and a mechanical device using the same.

Means for Solving the Problems

[0012] In order to solve the above problems, according to aspects of the invention, the following lubricating oil composition and mechanical device are provided.

(1) A lubricating oil composition containing: (A) organopolysiloxane; and (B) at least one of a sulfur compound, a phosphorus compound and a zinc compound, the lubricating oil composition having a kinematic viscosity not less than 1 mm^2/s and less than 40.0 mm^2/s at 100 degrees C.

(2) The lubricating oil composition, in which the component (B) is one of an extreme pressure agent and an antiwear agent.

(3) The lubricating oil composition further containing (C) a friction modifier.

(4) The lubricating oil composition, in which the component (C) is at least one of an oleic acid, oleylamine and oleic amide.

(5) The lubricating oil composition, in which the lubricating oil composition is adapted to be used in a mechanical device.

(6) The lubricating oil composition, in which the mechanical device is one of a hydraulic device, a stationary gear, an automobile transmission, a motor/battery cooling device and a joint.

(7) A mechanical device using the lubricating oil composition.

(8) The mechanical device, in which the mechanical device is one of a hydraulic device, a stationary gear, an automobile transmission, a motor/battery cooling device and a joint.

[0013] According to the aspects of the invention, it is possible to provide a lubricating oil composition that has an extremely high viscosity index (300 or more) and an excellent lubricity. The use of such a lubricating oil composition in industrial machines and mechanical devices such as an automobile transmission significantly contributes to energy saving.

DESCRIPTION OF EMBODIMENTS

[0014] A lubricating oil composition (hereinafter also referred to as "composition") according to an exemplary embodiment of the invention contains (A) organopolysiloxane and (B) at least one of a sulfur compound, a phosphorus compound and a zinc compound, and has a kinematic viscosity not less than 1 mm^2/s and less than 40.0 mm^2/s at 100 degrees C. The composition will be described below in detail.

[0015] The component (A) in the composition is organopolysiloxane. Organopolysiloxane is a general term for organic silicon compounds (i.e., so-called silicone). A skeleton represented by the following formula (1) is favorably usable as a basic skeleton of the organopolysiloxane (monomer unit).

$$RnSiO(4-n)/2 \quad (1)$$

[0016] Specific examples of R in the formula (1) are unsubstituted or substituted monovalent hydrocarbon groups selected from: alkyl groups such as a methyl group, ethyl group, propyl group and butyl group; alkenyl groups such as a vinyl group, allyl group and butenyl group; aryl groups such as a phenyl group and tolyl group; and a chloromethyl group, chloropropyl group, 3,3,3-trifluoropropyl group and 2-cyanoethyl group that are obtained by substituting a part or all of the hydrogen atoms bonded to carbon atoms of the above-listed groups with, for instance, a halogen atom and/or cyano group, the monovalent hydrocarbon groups preferably having 1 to 10 carbon atoms, more preferably 1 to 8 carbon atoms. The monovalent hydrocarbon groups may be the same or different. n is 1.90 to 2.05. The component (A) preferably has a linear molecular structure, but may include a branched-chain portion in a molecule. The component (A) may have a molecular chain end being terminated with a triorganosilyl group or hydroxyl group. Examples of the triorganosilyl group are a trimethylsilyl group, dimethylvinylsilyl group, methylphenylvinylsilyl group, methyldiphenylsilyl group, methyldivinylsilyl group and trivinylsilyl group. Among the above, dimethylpolysiloxane is particularly preferable.

[0017] In addition to the organopolysiloxane having the structure represented by the formula (1), so-called unreactive silicone oils including a polyether modified aralkyl type, fluoroalkyl type, long-chain alkyl type, long-chain alkyl/aralkyl type, higher fatty acid ester modified type, higher fatty acid amide modified type and a phenyl modified type are usable.

[0018] Incidentally, the polymerization degree of the organopolysiloxane is not subject to a particular limitation, but is preferably in a range from 100 to 2000 in order to keep the organopolysiloxane in a liquid phase.

[0019] By using the above-described organopolysiloxane as a base stock, a lubricating oil composition with a viscosity index of 300 or more can be easily obtained.

[0020] A ratio of the component (A) in the composition is preferably in a range from 80 mass % to 99.5 mass % of the total amount of the composition, more preferably from 90 mass % to 99 mass %. When the ratio of the component (A) is less than 80 mass %, the viscosity index is likely to fall. On the other hand, when the ratio of the component (A) is more than 99.5 mass %, the lubricity and the wear resistance are likely to be deteriorated.

[0021] The component (B) in the composition is at least one of a sulfur compound, a phosphorus compound and a zinc compound. Compounds containing the above elements provide an appropriate lubricity to organopolysiloxane when being blended therein (the reason, however, has not been clearly proven).

[0022] Substances capable of functioning as an extreme pressure agent or an antiwear agent are favorably usable as the component (B). For instance, examples of the sulfur compound are olefin sulfide, dialkylpolysulfide, diarylalkylpolysulfide and diarylpolysulfide. Examples of the phosphorus compound are phosphate, thiophosphate, phosphite, alkyl hydrogen phosphite, phosphate amine salt and phosphite amine salt. Examples of the zinc compound are zinc dithiophosphate (ZnDTP) and zinc dithiocarbamate (ZnDTC). Additionally, substances containing both phosphorus and sulfur such as sulfurized oxymolybdenum organophosphorodithioate (MoDTP) and sulfurized oxymolybdenum dithiocarbamate (MoDTC) are also preferable. One of the above substances may be singularly used or two or more thereof may be used in combination.

[0023] When the above-listed substance(s) is blended as the component (B), a content thereof is preferably in a range from 0.01 mass % to 5 mass % of the total amount of the composition, more preferably from 0.1 mass % to 3 mass %, further more preferably from 0.1 mass % to 2 mass %. When the content of the component (B) is excessively small, the lubricity is likely to be insufficient. On the other hand, when the content of the component (B) is excessively large, the component (B) is likely to be partly undissolved in organopolysiloxane, so that effects proportional to the content cannot always be obtained. Further, such an undissolved substance is likely to block a path for a lubricating oil.

[0024] A friction modifier is preferably further blended in the composition as the component (C).

Examples of the friction modifier are organic molybdenum compound, fatty acid, higher alcohol, fatty acid ester, oils and fats, amine, and amide. One of the above substances may be singularly used or two or more thereof may be used in combination.

[0025] Among the above, an oleic acid, oleylamine and oleic amide are particularly preferable in terms of reduction in friction coefficient and prevention of sound vibration.

[0026] A content of the friction modifier is not subject to a particular limitation, but is preferably in a range from 0.01 mass % to 10 mass % of the total amount of the composition.

[0027] A kinematic viscosity at 100 degrees C. of the composition is in a range not less than 1 mm^2/s and less than 40.0 mm^2/s, preferably in a range from 2 mm^2/s to 30 mm^2/s. When the kinematic viscosity at 100 degrees C. is less than 1 mm^2/s, the lubricity and the wear resistance are insufficient. On the other hand, when the kinematic viscosity at 100 degrees C. is more than 40.0 mm^2/s, a solubility of the above additive is lowered, so that the lubricity and the wear resistance are insufficient irrespective of the content of the additive. Further, when the kinematic viscosity at 100 degrees C. is 40.0 mm^2/s or more, the composition is unsuitable to machines intended to function as a transmission mechanism or a fluid-transfer mechanism because energy loss becomes large.

[0028] Incidentally, as long as the effects of the invention are not impaired, the composition may be further blended with a viscosity index improver, detergent dispersant, antioxidant, metal deactivator, rust inhibitor, surfactant/antiemulsifier, antifoaming agent, anticorrosive agent, oiliness agent, acid scavenger and the like as needed when being used.

[0029] Examples of the viscosity index improver are a non-dispersed polymethacrylate, dispersed polymethacrylate, olefin copolymer, dispersed olefin copolymer and styrene copolymer. Mass average molecular weights of the above exemplary viscosity index improvers, e.g., the dispersed polymethacrylate and the non-dispersed polymethacrylate, are preferably in a range from 5000 to 300000. A mass average molecular weight of the olefin copolymer is preferably in a range from 800 to 100000. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the viscosity index improver is not subject to a particular limitation, but is preferably in a range from 0.5 mass % to 15 mass % of the total amount of the composition, more preferably from 1 mass % to 10 mass %.

[0030] As the detergent dispersant, an ashless dispersant and a metal-based detergent dispersant are usable.

[0031] Examples of the ashless dispersant are a succinimide compound, boric imide compound, Mannich dispersant and acid amide compound. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the ashless dispersant is not subject to a particular limitation, but is preferably in a range from 0.1 mass % to 20 mass % of the total amount of the composition.

[0032] Examples of the metal-based detergent dispersant are an alkali metal sulfonate, alkali metal phenate, alkali metal salicylate, alkali metal naphthenate, alkaline earth metal sulfonate, alkaline earth metal phenate, alkaline earth metal salicylate and alkaline earth metal naphthenate. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the metal-based detergent dispersant is not subject to a particular limitation, but is preferably in a range from 0.1 mass % to 10 mass % of the total amount of the composition.

[0033] Examples of the antioxidant are an amine-based antioxidant, phenol-based antioxidant and sulfur-based antioxidant. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the antioxidant is not subject to a particular limitation, but is preferably in a range from 0.05 mass % to 7 mass % of the total amount of the composition.

[0034] Examples of the metal deactivator are a benzotriazole-based metal deactivator, tolyltriazole-based metal deactivator, thiadiazole-based metal deactivator and imidazole-based metal deactivator. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the metal deactivator is not subject to a particular limitation, but is preferably in a range from 0.01 mass % to 3 mass % of the total amount of the composition, more preferably from 0.01 mass % to 1 mass %.

[0035] Examples of the rust inhibitor are petroleum sulfonate, alkylbenzene sulfonate, dinonylnaphthalene sulfonate, alkenyl succinic ester and multivalent alcohol ester. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the rust inhibitor is not subject to a particular limitation, but is preferably in a range from 0.01 mass % to 1 mass % of the total amount of the composition, more preferably from 0.05 mass % to 0.5 mass %.

[0036] An example of the surfactant/anti-emulsifier is a polyalkylene-glycol-based nonionic surfactant. Specific examples thereof are polyoxyethylene alkyl ether, polyoxyethylene alkyl phenyl ether and polyoxyethylene alkyl naphthyl ether. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the surfactant is not subject to a particular limitation, but is preferably in a range from 0.01 mass % to 3 mass % of the total amount of the composition, more preferably from 0.01 mass % to 1 mass %.

[0037] Examples of the antifoaming agent are fluorosilicone oil and fluoroalkyl ether. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the antifoaming agent is not subject to a particular limitation, but is preferably in a range from 0.005 mass % to 0.5 mass % of the total amount of the composition, more preferably from 0.01 mass % to 0.2 mass %.

[0038] Examples of the anticorrosive agent are a benzotriazole-based anticorrosive agent, benzimidazole-based anticorrosive agent, benzothiazole-based anticorrosive agent and thiadiazole-based anticorrosive agent. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the anticorrosive agent is not subject to a particular limitation, but is preferably in a range from 0.01 mass % to 1 mass % of the total amount of the composition.

[0039] Examples of the oiliness agent are an aliphatic monocarboxylic acid, a polymeric fatty acid, a hydroxy fatty acid, an aliphatic monoalcohol, an aliphatic monoamine, an aliphatic monocarboxylic acid amide, and a partial ester of a polyhydric alcohol and an aliphatic monocarboxylic acid. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the oiliness agent is not subject to a particular limitation, but is preferably in a range from 0.01 mass % to 10 mass % of the total amount of the composition.

[0040] As the acid scavenger, an epoxy compound is usable. Specific examples thereof are phenyl glycidyl ether, alkyl glycidyl ether, alkylene glycol glycidyl ether, cyclohexene oxide, alpha-olefin oxide and epoxidized soybean oil. One of the above substances may be singularly used or two or more thereof may be used in combination. A content of the acid scavenger is not subject to a particular limitation, but is preferably in a range from 0.005 mass % to 5 mass % of the total amount of the composition.

[0041] The above-described lubricating oil composition according to the exemplary embodiment of the invention can exhibit lubricity (i.e., wear resistance, seizure resistance, etc.) while keeping a high viscosity index of organopolysiloxane because the kinematic viscosity falls within the predetermined range and the solubility of the additive(s) to organopolysiloxane can be maintained. Accordingly, the lubricating oil composition is favorably usable in a hydraulic device, a stationary gear, an automobile transmission, a motor/battery cooling device, a joint and the like.

EXAMPLES

[0042] With reference to Examples and Comparatives, the invention will be further specifically described. It should be noted that the invention is not limited by the description of Examples.

Examples 1 to 3, Comparatives 1 to 4 and Reference 1

[0043] A lubricating oil composition (a sample oil) intended to be replaceable was prepared according to a formulation for an industrial gear oil (ISO VG220) shown in Table 1 and the properties and friction/wear characteristics thereof were evaluated according to the following method. The commercially available gear oil (VG220) was also evaluated as Reference 1.

(1) Kinematic Viscosity (40 Degrees C., 80 Degrees C. and 100 Degrees C.) and Viscosity index

[0044] Measurement was conducted by a method according to JIS K 2283.

(2) Shell Four Ball Test:

[0045] A last nonseizure load (LNL, unit: N), a weld load (WL, unit: N) and a load-wear index (LWI, unit: N) were obtained under test conditions such as a revolution of 1800 rpm according to a method described in ASTM D2783.

TABLE 1

			Ex. 1	Ex. 2	Ex. 3	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Ref. 1
Formulation (mass %)	Base Stock	Silicone Oil 1[1)]	23	23	23	23	—	—	—	Commercial Gear Oil (VG220)
		Silicone Oil 2[2)]	76	75.5	76.2	77	—	—	—	
		Mineral Oil 150BS[3)]	—	—	—	—	60	60	60	
		Mineral Oil 500N[4)]	—	—	—	—	39	38.5	39.2	
	Additives	Sulfur Extreme Pressure Agent[5)]	1	0.8	—	—	1	0.8	—	
		Phosphorus Antiwear Agent[6)]	—	0.7	—	—	—	0.7	—	
		Zinc Antiwear Agent[7)]	—	—	0.8	—	—	—	0.8	
		Total	100	100	100	100	100	100	100	
Properties	40° C. Kinematic Viscosity (mm2/s)		97.0	98.5	97.3	96.7	215	228	229	220
	100° C. Kinematic Viscosity (mm2/s)		39.5	39.7	39.1	39.3	19.7	20.2	20.4	18.7
	Viscosity Index		416	413	412	415	105	102	103	95
Evaluation Results	Shell Four Ball Test (N)	LNL	314	490	314		618	785	490	618
		WL	1961	1761	1569	Seizure	1961	1569	1961	1569
		LWI	297	338	255		295	332	258	321

1) Silicone oil 1: dimethylpolysiloxane having a viscosity at 25 degrees C. of 350 mm^2/s

2) Silicone oil 2: dimethylpolysiloxane having a viscosity at 25 degrees C. of 100 mm^2/s

3) Mineral oil 150BS: hydrotreated paraffin-based mineral oil having a viscosity at 40 degrees C. of 459 mm^2/s

4) Mineral oil 500N: hydrotreated paraffin-based mineral oil having a viscosity at 40 degrees C. of 88.95 mm^2/s

5) Sulfuric extreme pressure agent: dithioglycolic acid n-octyl ester

6) Phosphorus antiwear agent: tricresyl phosphate

7) Zinc antiwear agent: isobutyldithio zinc salt (ZnDTP)

Evaluation Results

[0046] Considering the respective viscosity indexes of Examples 1 to 3 exceed 400, Examples 1 to 3 are significantly excellent in temperature dependence of viscosity as compared with Reference 1 that uses the commercially available gear oil (VG220) and Comparatives 2 to 4 that uses a mineral oil as a base stock. Further, the results of the Shell four ball test of Examples 1 to 3 are comparable to that of Reference 1. However, as shown in Comparative 1, the sole use of a silicone base stock lowers the seizure resistance while improving VI, so that seizure immediately occurs during the Shell four ball test.

[0047] In view of the above, by blending any one of a sulfur extreme pressure agent, a phosphorus antiwear agent and a zinc antiwear agent in a silicone oil (i.e., a base stock) and adjusting the kinematic viscosity of the resulting composition to the predetermined level, it is possible to obtain antiwear properties equal to or more than that of the commercially available gear oil while keeping the high VI characteristics of the silicone oil even though the silicone oil itself cannot exhibit such antiwear properties.

Examples 4 to 6, Comparatives 5 to 8 and References 2 and 3

[0048] A lubricating oil composition (a sample oil) was prepared according to a formulation for an industrial gear oil (VG32) shown in Table 2 and the properties and friction-wear characteristics thereof were evaluated according to the above method. The commercially available hydraulic oil (VG32) and a commercially available ATF were also evaluated as Reference 2 and Reference 3, respectively.

TABLE 2

			Ex. 4	Ex. 5	Ex. 6	Comp. 5	Comp. 6	Comp. 7	Comp. 8	Ref. 2	Ref. 3
Formulation (mass%)	Base Stock	Silicone Oil [1)]	99	73	25	75	—	—	—	Commercial Hydraulic Oil (VG32)	Commercial ATF
		Silicone Oil 4[2)]	—	25	73.5	25	—	—	—		
		Mineral Oil 150N[3)]	—	—	—	—	89	10			
		Mineral Oil 60N[4)]	—	—	—	—	—	68	74		
	Additives	Viscosity Index Improver[5)]	—	—	—	—	10	20	25		
		Sulfuric Extreme Pressure Agent[6)]	1	1	—	—	1	1	—		
		Phosphorus Antiwear Agent[7)]	—	0.5	—	—	—	0.5	—		
		Zinc Antiwear Agent[8)]	—	—	1	—	—	—	1		
		Alkaline FM[9)]	—	0.5	—	—	—	0.5	—		
		Acid FM[10)]	—	—	0.5	—	—	—	—		
		Total	100	100	100	100	100	100	100		
Properties	40° C. Kinematic Viscosity (mm2/s)		16.0	12.6	8.20	12.5	41.4	31.5	19.0	30.2	32.3
	100° C. Kinematic Viscosity (mm2/s)		7.21	5.46	3.80	5.50	7.50	7.21	5.28	5.34	7.48
	Viscosity Index		497	476	501	485	150	219	238	110	211

TABLE 2-continued

			Ex. 4	Ex. 5	Ex. 6	Comp. 5	Comp. 6	Comp. 7	Comp. 8	Ref. 2	Ref. 3
Evaluation	Shell Four	LNL	314	314	196		490	618	490	490	490
Results	Ball Test	WL	1569	1961	1236	Seizure	1961	1961	1569	1961	1569
	(N)	LWI	285	302	205		341	295	220	253	216

1) Silicone oil 3: dimethylpolysiloxane having a viscosity at 25 degrees C. of 20 mm^2/s

2) Silicone oil 4: dimethylpolysiloxane having a viscosity at 25 degrees C. of 10 mm^2/s

3) Mineral oil 150N: hydrotreated paraffin-based mineral oil having a viscosity at 100 degrees C. of 4.2 mm^2/s, VI 105

4) Mineral oil 60N: hydrotreated paraffin-based mineral oil having a viscosity at 100 degrees C. of 2.2 mm^2/s, VI 112

5) Viscosity index improver: polymethacrylate, mass average molecular weight: 35000

6) Sulfuric extreme pressure agent: dithioglycolic acid n-octyl ester

7) Phosphorus antiwear agent: tricresyl phosphate

8) Zinc antiwear agent: isobutyldithio zinc salt (ZnDTP)

9) Friction modifier (alkaline FM): oleylamine

10) Friction modifier (acid FM): oleic acid

Evaluation Results

[0049] Each of sample oils of Examples 4 to 6 is prepared by blending a silicone base stock having a relatively low viscosity with an extreme pressure agent such as a sulfur extreme pressure agent. Compared with the commercially available hydraulic oil (VG32) of Reference 2 and the commercially available ATF of Reference 3, it is found that the kinematic viscosities at 100 degrees C. of the Examples are approximately the same as those of References 2 and 3 while the kinematic viscosities at 40 degrees C. of the Examples are approximately half of those of References 2 and 3.

[0050] The sample oil of Comparative 5 only contains a silicone oil, so that seizure immediately occurs. However, when being blended with a predetermined additive as in Examples 4 to 6, the sample oil becomes effective for reducing friction at a low temperature while keeping the high viscosity index of the silicone oil.

[0051] Incidentally, the sample oil of Example 5 is prepared by: further lowering a viscosity of the sample oil of Example 4; blending the sample oil with a phosphorus antiwear agent to compensate deterioration of the wear resistance resulting from the lowering of the viscosity; and further blending the sample oil with a friction modifier (an alkaline FM) such as oleylamine. A sample oil of Example 6 has a further lowered viscosity. However, by blending a zinc antiwear agent and an acid FM, the sample oil can exhibit a required seizure resistance. It is notable that even when the viscosity is lowered as described above, both high VI and lubricity (i.e., seizure resistance, etc.) can be obtained.

[0052] Comparative 6 is prepared by using a mineral oil as a base stock according to the technique of Example 4. A seizure resistance of Example 4 exceeds that of Example 4 after a sulfur extreme pressure agent is blended in the mineral oil. However, even though a viscosity index improver is blended in order to improve a viscosity index of the sample oil of Comparative 6, the viscosity index is increased only to 150, which is half or less of that of the sample oil of the Example. Each of Comparatives 7 and 8 uses a mineral oil as a base stock and the content of a viscosity index improver added thereto is increased with the expectation of a higher viscosity index. The mineral oil (i.e., a base stock) is experimentally blended with more amount of a viscosity index improver after the viscosity thereof is lowered to a practical limit (excessively lowering the viscosity of a base stock practically becomes a problem because a flash point is also lowered). As a result, even the viscosity indexes of the sample oils of Comparatives 7 and 8 are improved only to 219 and 238, respectively. These viscosity indexes are half or less of that of the sample oil of Example and thus it is understood that a high viscosity index of 300 or more cannot be achieved.

1. A lubricating oil composition comprising:

(A) an organopolysiloxane; and

(B) at least one compound selected from the group consisting of a sulfur compound, a phosphorus compound and a zinc compound,

wherein the lubricating oil composition has a kinematic viscosity not less than 1 mm^2/s and less than 40.0 mm^2/s at 100 degrees C.

2. The lubricating oil composition of claim **1**, wherein the component (B) is an extreme pressure agent or an antiwear agent.

3. The lubricating oil composition of claim **1**, further comprising (C) a friction modifier.

4. The lubricating oil composition of claim **3**, wherein the component (C) is at least one member selected from the group consisting of an oleic acid, oleylamine and oleic amide.

5. The lubricating oil composition of claim **1**, wherein the lubricating oil composition is adapted to be used in a mechanical device.

6. The lubricating oil composition of claim **5**, wherein the mechanical device is selected from the group consisting of a hydraulic device, a stationary gear, an automobile transmission, a motor/battery cooling device and a joint.

7. A mechanical device comprising the lubricating oil composition of claim **5**.

8. The mechanical device of claim **7**, wherein the mechanical device is selected from the group consisting of a hydraulic device, a stationary gear, an automobile transmission, a motor/battery cooling device and a joint.

9. The lubricating oil composition of claim **1**, wherein the component (B) is an extreme pressure agent.

10. The lubricating oil composition of claim **1**, wherein the component (B) is an antiwear agent.

11. The lubricating oil composition of claim **1**, wherein the component (B) comprises a sulfur compound.

12. The lubricating oil composition of claim **1**, wherein the component (B) comprises a phosphorus compound.

13. The lubricating oil composition of claim **1**, wherein the component (B) comprises a zinc compound.

14. The lubricating oil composition of claim **2**, further comprising (C) a friction modifier.

15. The lubricating oil composition of claim **3**, wherein the component (C) comprises an oleic acid.

16. The lubricating oil composition of claim **3**, wherein the component (C) comprises oleylamine.

17. The lubricating oil composition of claim **3**, wherein the component (C) comprises oleic amide.

18. The lubricating oil composition of claim **14**, wherein the component (C) comprises an oleic acid.

19. The lubricating oil composition of claim **14**, wherein the component (C) comprises oleylamine.

20. The lubricating oil composition of claim **14**, wherein the component (C) comprises oleic amide.

* * * * *