(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 June 2011 (16.06.2011)

PCT

(10) International Publication Number
WO 2011/070141 A2

(51) International Patent Classification: Not classified

(21) International Application Number:
PCT/EP2010/069353

(22) International Filing Date:
10 December 2010 (10.12.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2009-280730 10 December 2009 (10.12.2009) JP
2010-271967 6 December 2010 (06.12.2010) JP

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

WO 2011/070141 A2

(54) **Title**: LUBRICATING OIL COMPOSITION

(57) **Abstract**: Lubricating oil composition comprising a succinic acid derivative and an epoxy compound as additives, and a base oil selected from a mineral oil, a synthetic oil, and mixtures thereof, wherein the base oil has a sulphur content of not more than 0.3% by mass. The lubricating oil composition of the present invention has good rust-preventing properties, low sludge and also excellent energy saving characteristics through having a low friction coefficient, and can be used as an industrial lubricating oil, in particular for machine oils, hydraulic oils, turbine oils, compressor oils, gear oils and bearing oils.

LUBRICATING OIL COMPOSITION

Field of the Invention

This invention relates to lubricating oil compositions such as industrial lubricating oils using refined base oils, and in particular it relates to lubricating oil compositions useful as machine oils, hydraulic oils, turbine oils, compressor oils, gear oils and bearing oils.

Background of the Invention

Good rust-preventing properties and friction characteristics are required of lubricating oil compositions, including those used as industrial lubricating oil compositions. If they have a low friction coefficient (μ), it is possible efficiently to reduce friction losses in mechanical apparatus and to achieve high energy savings.

For example, hydraulic apparatus is widely used in construction machinery and the like, and if the friction coefficient of the lubricating oils used for the hydraulic oil actuating the machinery is high, the phenomenon of minute stick-slip may occur in the sliding friction parts of the packing owing to the reciprocating movement of the hydraulic cylinders, and chatter, vibration, squealing and other abnormal sounds may occur in the cylinders, so that it becomes impossible to control the hydraulic plant with satisfactory precision (Japanese Laid-open Patent H9-111277 (1997)). As a consequence it is necessary to reduce the friction coefficient of the lubricating oil so that the hydraulic cylinders move accurately and smoothly.

A fundamental requirement to maintain performance of a lubricating oil used in mechanical apparatus is rust prevention. This is because the lubricating oil temperature within tanks in the mechanical apparatus rises and falls in accordance with conditions of use, and therefore the lubricating oil within the tanks may be subject to admixture with condensed water, or to admixture with moisture because of leaks from cooling-water pipes.

This invention is intended to reduce the friction coefficient exhibited by lubricating oils so as to obtain an industrial lubricating oil which offers high energy savings. In addition, the intention is that, if such a lubricating oil composition is used as a hydraulic oil in hydraulic apparatus, the phenomena of chatter, vibration, squealing and other abnormal sounds in the cylinders will not occur, so that it will become possible to control the hydraulic apparatus with satisfactory precision and to inhibit the occurrence of rust and so impart excellent rust-prevention properties. The intention is, by this means, to obtain a lubricating oil composition which has excellent rust-prevention properties, which offers substantial energy savings and which has good operating efficiency.

Summary of the Invention

According to the present invention there is provided a lubricating oil composition, such as a hydraulic oil, comprising a succinic acid derivative and an epoxy compound as additives, and a base oil selected from a refined mineral oil and a synthetic oil, and mixtures thereof, wherein the base oil has a sulphur content of not more than 0.3% by mass.

Further, it is possible to obtain a lubricating oil composition with even better rust-prevention properties and with superior energy savings by further adding at least one kind of amine compound, amide compound or polyhydric alcohol ester as an additive.

According to this invention, it is possible to obtain a lubricating oil composition with substantial rust prevention by minimising the occurrence of the sludge that occurs in all kinds of industrial apparatus and by inhibiting the occurrence of rust. In addition, it is possible to reduce the friction losses to great effect and to bring about energy savings. Also, in the case of use as a hydraulic oil, it is possible to control the hydraulic apparatus with precision by reducing the friction coefficient and so not giving rise to phenomena in the hydraulic apparatus such as chatter, vibrations, squealing and other abnormal sounds in the hydraulic cylinders.

Detailed Description of the Invention

For the base oil of the present lubricating oil composition it is possible to use highly refined oils which are mineral oils or synthetic oils as normally used for lubricating oils and which have a sulphur content of less than about 0.3% by mass. In particular it is possible to use, singly or as mixtures, base oils which belong to Group II, Group III and Group IV of the API (American Petroleum Institute) base oil categories.

Group II base oils include, for example, paraffinic mineral oils obtained by a suitable combination of refining processes such as hydrorefining and dewaxing in respect of lubricating oil fractions obtained by atmospheric distillation of crude oil. Group II base oils refined by hydrorefining methods such as the Gulf Company

method have a total sulphur content of less than 10 ppm and an aromatic content of not more than 5% and so are suitable for this invention. The viscosity of these base oils is not specially limited, but the viscosity index should be 90 to 125 and preferably 100 to 120. The kinetic viscosity at 40°C should preferably be 2 to 680 mm^2/s and more preferably 8 to 220 mm^2/s. Also, the total sulphur content should be less than 700 ppm, preferably less than 500 ppm and even more preferably less than 10 ppm. The total nitrogen content should also be less than 10 ppm and preferably less than 1 ppm. In addition, oils with an aniline point of 80 to 150°C and preferably 100 to 135°C should be used.

Suitable Group III base oils and Group II+ base oils include, for example, paraffinic mineral oils manufactured by a high degree of hydrorefining in respect of lubricating oil fractions obtained by atmospheric distillation of crude oil, base oils refined by the Isodewax process which dewaxes and substitutes the wax produced by the dewaxing process with isoparaffins, and base oils refined by the Mobil wax isomerisation process. The viscosity of these base oils is not specially limited, but the viscosity index should be 95 to 145 and preferably 100 to 140. The kinetic viscosity at 40°C should preferably be 2 to 680 mm^2/s and more preferably 8 to 220 mm^2/s. Also, the total sulphur content should be 0 to 100 ppm and preferably less than 10 ppm. The total nitrogen content should also be less than 10 ppm and preferably less than 1 ppm. In addition, oils with an aniline point of 80 to 150°C and preferably 110 to 135°C should be used.

As examples of synthetic oils mention may be made of polyolefins, alkylbenzenes, alkylnaphthalenes, esters,

polyoxyalkylene glycols, polyphenyl ethers, dialkyldiphenyl ethers, fluorine-containing compounds (perfluoropolyethers, fluorinated polyolefins) and silicone oils.

The aforementioned polyolefins include polymers of various olefins or hydrides thereof. Any olefin may be used, and as examples mention may be made of ethylene, propylene, butene and α-olefins with five or more carbons. In the manufacture of polyolefins, one kind of the aforementioned olefins may be used singly or two or more kinds may be used in combination. Particularly suitable are the polyolefins called poly-α-olefins (PAO). These are base oils of Group IV.

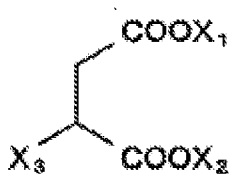
The viscosity of these synthetic oils is not specially limited, but the kinetic viscosity at 40°C should preferably be 2 to 680 mm^2/s and more preferably 8 to 220 mm^2/s.

GTLs (gas to liquid) synthesised by the Fischer-Tropsch method of converting natural gas to liquid fuel have a very low sulphur content and aromatic content compared with mineral oil base oils refined from crude oil and have a very high paraffin constituent ratio, and so have excellent oxidative stability, and because they also have extremely small evaporation losses, they are suitable as base oils for this invention. The viscosity of GTL base oils is not specially limited, but normally the viscosity index should be 130 to 180 and preferably 140 to 175. Also, the kinetic viscosity at 40°C should be 2 to 680 mm^2/s and preferably 5 to 120 mm^2/s. Normally the total sulphur content is also less than 10 ppm and the total nitrogen content less than 1 ppm. A commercial example of such a GTL base oil is Shell XHVI (registered trademark).

The sulphur content in the base oil component of the lubricating oil composition of this invention is not more than 0.3% by mass, preferably not more than 1000 ppm, more preferably not more than 100 ppm and even more preferably not more than 10 ppm.

The amount of the aforementioned base oil to be incorporated in the present lubricating oil composition is not specially limited, but, taking as a basis the total amount of the lubricating oil composition, should be at least 60% by mass, preferably at least 80% by mass, more preferably at least 90% by mass, and yet more preferably at least 95% by mass.

The succinic acid derivatives are as shown by general formula (1):



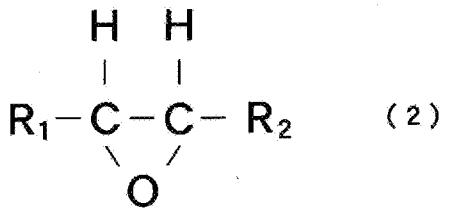
(1)

In the aforementioned general formula 1, X_1 and X_2 are each hydrogen or alkyl groups, alkenyl groups or hydroxyalkyl groups having from 3 to 6 carbon atoms which may be the same or different, and preferably should be hydrogen atoms, 1-hydroxypropyl groups, 2-hydroxypropyl groups, 2-methylpropyl groups or tertiary butyl groups. X_3 has from 1 to 30 carbons and is an alkyl group or an alkenyl group, or an alkyl group having ether bonds, or a hydroxyalkyl group, for example, a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, a heptyl group, an octyl group, a 2-ethylhexyl group, a nonyl group, a decyl group, an undecyl group, a dodecyl group, a dodecylene group, a tridecyl group, a tetradecyl group, a tetradecylene

group, a pentadecyl group, a hexadecyl group, a heptadecyl group, an octadecyl group, an octadecylene group, an eicosyl group, a docosyl group, an alkoxypropyl group, a 3-(C_6-C_{18})hydrocarbonoxy(C_3-C_6) alkyl group, and more preferably a tetraisopropyl group, an oleyl group, a cyclohexyloxypropyl group, a 3-octyloxypropyl group, a 3-isooctyloxypropyl group, a 3-decyloxypropyl group, a 3-isodecyloxypropyl group and a 3-(C_{12}-C_{16})alkoxypropyl group are suitable. Aminated forms of these compounds are also suitable.

The aforementioned succinic acid derivatives should have an acid number as determined by JIS K2501 in the range of from 10 to 300 mgKOH/g and preferably in the range of from 30 to 200 mgKOH/g. The amount of succinic acid derivatives used in the lubricating oil composition is in the range of from 0.001 to 0.5% by mass, preferably in the range of from 0.001 to 0.1% by mass and more preferably in the range of from 0.005 to 0.1% by mass. One kind or a mixture of several kinds of these succinic acid derivatives may be used.

The aforementioned epoxy compounds are aliphatic epoxy compounds and include the epoxy compounds shown by the following general formula (2):



(2)

In the aforementioned general formula 2, R_1 is hydrogen (H) or a linear or branched alkyl group or alkenyl group having from 1 to 22 carbon atoms. R_2 is hydrogen (H) or a linear or branched alkyl group or alkenyl group having from 1 to 22 carbon atoms, or a "—

R_3—COOH" group, a "—R_3—$COOR_4$" group or a "—OH" group. (The aforementioned R_3 is a linear or branched alkylene group or alkenylene group having from 1 to 22 carbon atoms, and R_4 is a linear or branched alkyl group or alkenyl group having from 1 to 22 carbon atoms).

For the epoxy compounds exemplified by the aforementioned general formula 2, mention may be made of those known as olefin oxides, being epoxidised alkenyl compounds. Examples are octene oxide, nonene oxide, decene oxide, undecene oxide, dodecene oxide, tridecene oxide, tetradecene oxide, pentadecene oxide, hexadecene oxide, heptadecene oxide, octadecene oxide and, with epoxidised terminals, alpha-decene oxide, alpha-dodecene oxide, alpha-tetradecene oxide, alpha-hexadecene oxide and alpha-octadecene oxide.

Other epoxy compounds are those manufactured by epoxidising rapeseed oil, soybean oil, linseed oil, castor oil, coconut oil, palm oil, palm kernel oil, sunflower oil, rice bran oil, safflower oil, beef tallow, pork tallow and so on. Mention may be made of the epoxidised fatty acid glycerides known as epoxidised rapeseed oil, epoxidised soybean oil, epoxidised linseed oil, epoxidised castor oil and epoxidised safflower oil.

Epoxy compounds other than the aforementioned epoxy compounds include those manufactured by epoxidising fatty acid ester compounds obtained from rapeseed oil, soybean oil, linseed oil, castor oil, coconut oil, palm oil, palm kernel oil, sunflower oil, rice bran oil, safflower oil, beef tallow, pork tallow and so on. Mention may be made of epoxidised rapeseed oil esters, epoxidised soybean oil esters, epoxidised linseed oil esters, epoxidised castor oil esters and epoxidised safflower oil esters.

Also, the alcohol residues of these esters are alkyl

groups, or alkyl groups having ether bonds, or hydroxyalkyl groups, and more preferably are butyl groups, isobutyl groups and 2-ethylhexyl groups. As examples, mention may be made of epoxidised methyl stearate, epoxidised butyl stearate, epoxidised octyl stearate, epoxidised rapeseed oil fatty acid isobutyl ester, epoxidised rapeseed oil fatty acid 2-ethylhexyl ester and epoxidised linseed oil fatty acid butyl ester. The main constituents of ordinary rapeseed oil fatty acids are fatty acids having 18 carbons with oleic acid 63%, linoleic acid 20% and linolenic acid 8%. The main constituents of linseed fatty acids are fatty acids having 18 carbons with oleic acid 21%, linoleic acid 13% and linolenic acid 57%.

These epoxy compounds are well known as rubber and plastic plasticisers and stabilisers. The amount of epoxy compound to be blended in the lubricating oil composition is in the range of from 0.01 to 5% by mass, but preferably in the range of from 0.01 to 2% by mass and more preferably in the range of from 0.01 to 1% by mass.

The amine compounds include aliphatic amines and the alkyl amines shown by the following general formula (3):

$$(R_5)_n\ NH_{3-n} \qquad (3)$$

In Formula 3, R_5 is a straight-chain saturated or unsaturated alkyl group having from 6 to 30 carbons, and n is integer 1 or 2.

The alkyl amines exemplified by the aforementioned general formula (3) include, as primary amines, those shown by the following general formula (4):

$$H_2N{-}X_5 \qquad (4)$$

In the aforementioned general formula 4, X_5 is an alkyl group or alkenyl group having from 1 to 30 carbon atoms. As examples of such compounds, mention may be made of laurylamine, coconut amine, n-tridecylamine, myristylamine, n-pentadecylamine, n-palmitylamine, n-heptadecylamine, n-stearylamine, isostearylamine, n-nonadecylamine, n-eicosylamine, n-heneicosylamine, n-docosylamine, n-tricosylamine, n-pentacosylamine, oleylamine, beef tallow amine, hydrogenated beef tallow amine and soybean amine. The number of carbon atoms in X_5 should preferably be in the range of from 8 to 24, and more preferably in the range of from 12 to 18. Also, X_5 may be a straight-chain aliphatic, a branched aliphatic or a tertiary alkyl group.

As examples of secondary amines, mention may be made of dilaurylamine, di-coconut amine, di-n-tridecylamine, di-n-myristylamine, di-n-pentadecylamine, di-n-palmitylamine, di-n-heptadecylamine, di-n-stearylamine, diisostearylamine, di-n-nonadecylamine, di-n-eicosylamine, di-n-heneicosylamine, di-n-docosylamine, di-n-tricosylamine, di-n-pentacosylamine, dioleylamine, di-beef tallow amine, di-hydrogenated beef tallow amine and di-soybean amine.

The fatty acid amines include also the diamines shown by the following general formula (5):

$$X_6—HN—X_7—NH_2 \qquad (5)$$

In the aforementioned general formula 5, X_6 is an alkyl group or alkenyl group having from 1 to 30 carbon atoms. The number of carbons in X_6 is preferably in the range of from 8 to 24 and more preferably in the range of

from 12 to 18. X_7 is an alkylene group having from 1 to 12 carbon atoms. The number of carbon atoms in X_7 is preferably in the range of from 1 to 8 and more preferably in the range of from 2 to 4.

Examples of diamine compounds such as those of general formula 5 include ethylenediamines such as N-octyl-1,2-ethylenediamine, N-nonyl-1,2-ethylenediamine, N-decyl-1,2-ethylenediamine, N-undecyl-1,2-ethylenediamine, N-lauryl-1,2-ethylenediamine, N-tridecyl-1,2-ethylenediamine, N-myristyl-1,2-ethylenediamine, N-tetradecyl-1,2-ethylenediamine, N-pentadecyl-1,2-ethylenediamine, N-palmityl-1,2-ethylenediamine, N-heptadecyl-1,2-ethylenediamine, N-oleyl-1,2-ethylenediamine, N-stearyl-1,2-ethylenediamine, N-isostearyl-1,2-ethylenediamine, N-nonadecyl-1,2-ethylenediamine, N-eicosyl-1,2-ethylenediamine, N-coconut-1,2-ethylenediamine, N-beef tallow-1,2-ethylenediamine, N-hydrogenated beef tallow-1,2-ethylenediamine and N-soybean-1,2-ethylenediamine.

Examples of propylenediamines include N-octyl-1,3-propylenediamine, N-nonyl-1,3-propylenediamine, N-decyl-1,3-propylenediamine, N-undecyl-1,3-propylenediamine, N-lauryl-1,3-propylenediamine, N-tridecyl-1,3-propylenediamine, N-myristyl-1,3-propylenediamine, N-tetradecyl-1,3-propylenediamine, N-pentadecyl-1,3-propylenediamine, N-palmityl-1,3-propylenediamine, N-heptadecyl-1,3-propylenediamine, N-oleyl-1,3-propylenediamine, N-stearyl-1,3-propylenediamine, N-isostearyl-1,3-propylenediamine, N-nonadecyl-1,3-propylenediamine, N-eicosyl-1,3-propylenediamine, N-coconut-1,3-propylenediamine, N-beef tallow-1,3-propylenediamine, N-hydrogenated beef tallow-1,3-propylenediamine and N-soybean-1,3-propylenediamine.

Examples of butylenediamines include N-octyl-1,4-butylenediamine, N-nonyl-1,4-butylenediamine, N-decyl-1,4-butylenediamine, N-undecyl-1,4-butylenediamine, N-lauryl-1,4-butylenediamine, N-tridecyl-1,4-butylenediamine, N-myristyl-1,4-butylenediamine, N-tetradecyl-1,4-butylenediamine, N-pentadecyl-1,4-butylenediamine, N-palmityl-1,4-butylenediamine, N-heptadecyl-1,4-butylenediamine, N-oleyl-1,4-butylenediamine, N-stearyl-1,4-butylenediamine, N-isostearyl-1,4-butylenediamine, N-nonadecyl-1,4-butylenediamine, N-eicosyl-1,4-butylenediamine, N-coconut-1,4-butylenediamine, N-beef tallow-1,4-butylenediamine, N-hydrogenated beef tallow-1,4-butylenediamine and N-soybean-1,4-butylenediamine.

As examples of aliphatic amines, mention may also be made of the amines shown by the following general formula (6):

$$X_8—N—(X_9)_2 \qquad (6)$$

In the aforementioned general formula 6, X_8 is an alkyl group or alkenyl group having from 1 to 30 carbon atoms. The number of carbon atoms in X_8 is preferably in the range of from 1 to 20 and more preferably in the range of from 1 to 8 or in the range of from 12 to 18. X_9 is an alkyl group, an alkenyl group or a hydroxyalkyl group having from 1 to 20 carbon atoms. The number of carbon atoms in X_9 is preferably in the range of from 1 to 8 or in the range of from 12 to 18.

Assuming X_8 is a methyl group, examples of dialkylmethylamines include dioctylmethylamine, dinonylmethylamine, didecylmethylamine, diundecylmethylamine, dilaurylmethylamine, ditridecylmethylamine, dimyristylmethylamine, ditetradecylmethylamine, dipentadecylmethylamine,

dipalmitylmethylamine, diheptadecylmethylamine, dioleylmethylamine, distearylmethylamine, diisostearylmethylamine, dinonadecylmethylamine, dieicosylmethylamine, di-coconut methylamine, di-beef tallow methylamine, di-hydrogenated beef tallow methylamine and di-soybean methylamine.

Assuming X_9 is a methyl group, examples of alkyldimethylamines include octyldimethylamine, nonyldimethylamine, decyldimethylamine, undecyldimethylamine, lauryldimethylamine, tridecyldimethylamine, myristyldimethylamine, tetradecyldimethylamine, pentadecyldimethylamine, palmityldimethylamine, heptadecyldimethylamine, oleyldimethylamine, stearyldimethylamine, isostearyldimethylamine, nonadecyldimethylamine, eicosyldimethylamine, coconut dimethylamine, beef tallow dimethylamine, hydrogenated beef tallow dimethylamine and soybean dimethylamine.

Assuming X_9 is a hydroxyalkyl group, examples of N-alkyldiethanolamines include N-octyldiethanolamine, N-nonyldiethanolamine, N-decyldiethanolamine, N-undecyldiethanolamine, N-lauryldiethanolamine, N-tridecyldiethanolamine, N-myristyldiethanolamine, N-tetradecyldiethanolamine, N-pentadecyldiethanolamine, N-palmityldiethanolamine, N-heptadecyldiethanolamine, N-oleyldiethanolamine, N-stearyldiethanolamine, N-isostearyldiethanolamine, N-nonadecyldiethanolamine, N-eicosyldiethanolamine, N-coconut diethanolamine, N-beef tallow diethanolamine, N-hydrogenated beef tallow diethanolamine and N-soybean diethanolamine, and examples of N-alkyldipropanolamines include N-octyldipropanolamine, N-nonyldipropanolamine, N-decyldipropanolamine, N-undecyldipropanolamine, N-

lauryldipropanolamine, N-tridecyldipropanolamine, N-myristyldipropanolamine, N-tetradecyldipropanolamine, N-pentadecyldipropanolamine, N-palmityldipropanolamine, N-heptadecyldipropanolamine, N-oleyldipropanolamine, N-stearyldipropanolamine, N-isostearyldipropanolamine, N-nonadecyldipropanolamine, N-eicosyldipropanolamine, N-coconut dipropanolamine, N-beef tallow dipropanolamine, N-hydrogenated beef tallow dipropanolamine and N-soybean dipropanolamine.

At least one kind of these aliphatic amines selected from the aforementioned groups may be used in the lubricating oil composition in an amount in the range of from 0.005 to 5% by mass, but preferably in the range of from 0.01 to 1% by mass.

For the amide compounds in this invention, mention may be made of the amide compounds, shown in general formula (7), which are products based on fatty acids and monoamines, or amide compounds which are the reaction products of fatty acids and polyamines:

$$X_{10}CONH_2 \qquad (7)$$

Assuming the amide compound is based on a fatty acid and a monoamine, in the aforementioned general formula 7, X_{10} is an alkyl group or alkenyl group having from 1 to 30 carbons. For example, mention may be made of laurylamide, coconut amide, n-tridecylamide, myristylamide, n-pentadecylamide, n-palmitylamide, n-heptadecylamide, n-stearylamide, isostearylamide, n-nononadecylamide, n-eicosylamide, n-heneicosylamide, n-docosylamide, n-tricosylamide, n-pentacosylamide, oleylamide, beef tallow amide, hydrogenated beef tallow amide and soybean amide. The number of carbon atoms in

X_{10} is preferably in the range of from 8 to 24 and more preferably in the range of from 12 to 18. The alkyl group or alkenyl group may also be a straight-chain aliphatic, a branched aliphatic or a tertiary alkyl group.

Assuming the amide compound is based on a polyamine and a fatty acid, mention may be made for example of reaction products of aliphatic amines or polyalkylene polyamines and saturated or unsaturated fatty acids having from 1 to 24 carbon atoms, such as isostearic acid triethylene tetramide, isostearic acid tetraethylene pentamide, oleic acid diethylene triamide and oleic acid diethanol amide.

The amide compounds are used in the lubricating oil composition in an amount in the range of from 0.001 to 0.5% by mass, preferably in the range of from 0.001 to 0.1% by mass and more preferably in the range of from 0.005 to 0.1 % by mass. These amide compounds may be used singly or in mixtures.

It is possible to incorporate esters of polyhydric alcohols in the lubricating oil composition of this invention. These polyhydric alcohol esters are those used in the prior art as oiliness improvers. For example, it is possible to use partial or complete esters of saturated or unsaturated fatty acids having from 1 to 24 carbons and polyhydric alcohols such as glycerol, sorbitol, alkylene glycol, neopentyl glycol, trimethylolpropane, pentaerythritol and xylidol.

As specific examples of such, mention may be made of glycerol esters such as glycerol monolaurylate, glycerol monostearate, glycerol monopalmitate, glycerol monooleate, glycerol dilaurylate, glycerol distearate, glycerol dipalmitate and glycerol dioleate.

For sorbitol esters mention may be made of sorbitol

monolaurylate, sorbitol monopalmitate, sorbitol monostearate, sorbitol monooleate, sorbitol dilaurylate, sorbitol dipalmitate, sorbitol distearate, sorbitol dioleate, sorbitol tristearate, sorbitol trilaurylate, sorbitol trioleate, sorbitol sesquioleate and sorbitol tetraoleate.

Alkylene glycol esters include ethylene glycol monolaurylate, ethylene glycol monostearate, ethylene glycol monooleate, ethylene glycol dilaurylate, ethylene glycol distearate, ethylene glycol dioleate, propylene glycol monolaurylate, propylene glycol monostearate, propylene glycol monooleate, propylene glycol dilaurylate, propylene glycol distearate and propylene glycol dioleate.

For neopentyl glycol esters mention may be made of neopentyl glycol monolaurylate, neopentyl glycol monostearate, neopentyl glycol monooleate, neopentyl glycol dilaurylate, neopentyl glycol distearate and neopentyl glycol dioleate.

Trimethylolpropane esters include trimethylolpropane monolaurylate, trimethylolpropane monostearate, trimethylolpropane monooleate, trimethylolpropane dilaurylate, trimethylolpropane distearate and trimethylolpropane dioleate.

Pentaerythritol esters include pentaerythritol monolaurylate, pentaerythritol monostearate, pentaerythritol monooleate, pentaerythritol dilaurylate, pentaerythritol distearate, pentaerythritol dioleate and dipentaerythritol monooleate.

For such fatty acid esters of polyhydric alcohols it is preferable to use partial esters of polyhydric alcohols and unsaturated fatty acids.

These fatty acid esters of polyhydric alcohols are

used in the lubricating oil composition in an amount in the range of from 0.01 to 5% by mass, but preferably in the range of from 0.05 to 2% by mass. If the amount used is outside this range, the effect on reducing the friction coefficient may be weakened.

Apart from the aforementioned constituents, it is possible, in order to improve performance further, to make appropriate use, as required, of various additives. Mention may be made of anti-oxidants, metal deactivators, extreme-pressure additives, oiliness improvers, defoaming agents, viscosity index improvers, pour-point depressants, detergent dispersants, rust preventatives, demulsifiers and so on, as well as other known lubricating oil additives.

For the anti-oxidants used in this invention, those used in lubricating oils are preferred for practical use, and mention may be made of phenolic anti-oxidants, amine-based anti-oxidants and sulphur-based anti-oxidants. These anti-oxidants may be used in the lubricating oil composition singly or in mixtures in the range of from 0.01 to 5% by mass.

As examples of the aforementioned amine-based anti-oxidants, mention may be made of dialkyldiphenylamines such as p,p'-dioctyldiphenylamine (Nonflex OD-3, made by Seiko Chemical Ltd), p,p'-di-α-methylbenzyldiphenylamine and N-p-butylphenyl-N-p'-octylphenylamine, monoalkyldiphenylamines such as mono-t-butyldiphenylamine and monooctyldiphenylamine, bis(dialkylphenyl)amines such as di(2,4-diethylphenyl)amine and di(2-ethyl-4-nonylphenyl)amine, alkylphenyl-1-naphthylamines such as octylphenyl-1-naphthylamine and N-t-dodecylphenyl-1-naphthylamine, 1-naphthylamine, arylnaphthylamines such as phenyl-1-naphthylamine, phenyl-2-naphthylamine, N-

hexylphenyl-2-naphthylamine and N-octylphenyl-2-naphthylamine, phenylenediamines such as N,N'-diisopropyl-p-phenylenediamine and N,N'-diphenyl-p-phenylenediamine, and phenothiazines such as Phenothiazine (made by Hodogaya Chemical Ltd.) and 3,7-dioctylphenothiazine.

As examples of sulphur-based anti-oxidants, mention may be made of dialkyl sulphides such as didodecyl sulphide and dioctadecyl sulphide, thiodipropionate esters such as didodecyl thiodipropionate, dioctadecyl thiodipropionate, dimyristyl thiodipropionate and dodecyloctadecyl thiodipropionate, and 2-mercaptobenzoimidazole.

Phenolic anti-oxidants include 2-t-butylphenol, 2-t-butyl-4-methylphenol, 2-t-butyl-5-methylphenol, 2,4-di-t-butylphenol, 2,4-dimethyl-6-t-butylphenol, 2-t-butyl-4-methoxyphenol, 3-t-butyl-4-methoxyphenol, 2,5-di-t-butylhydroquinone (Antage DBH, made by Kawaguchi Chemical Industry Co. Ltd.), 2,6-di-t-butylphenol, 2,6-di-t-butyl-4-alkylphenols such as 2,6-di-t-butyl-4-methylphenol and 2,6-di-t-butyl-4-ethylphenol, and 2,6-di-t-butyl-4-alkoxyphenols such as 2,6-di-t-butyl-4-methoxyphenol and 2,6-di-t-butyl-4-ethoxyphenol.

Also, there are 3,5-di-t-butyl-4-hydroxybenzylmercapto-octylacetate, alkyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionates such as n-octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate (Yoshinox SS, made by Yoshitomi Fine Chemicals Ltd.), n-dodecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate and 2'-ethylhexyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate and benzenepropanoic acid 3,5-bis(1,1-dimethyl-ethyl)-4-hydroxy-C7~C9 side-chain alkyl esters (Irganox L135, made by Ciba Specialty Chemicals Ltd.), 2,6-di-t-butyl-α-

dimethylamino-p-cresol, and 2,2'-methylenebis(4-alkyl-6-t-butylphenol)s such as 2,2'-methylenebis(4-methyl-6-t-butylphenol) (Antage W-400, made by Kawaguchi Chemical Industry Ltd.) and 2,2'-methylenebis(4-ethyl-6-t-butylphenol) (Antage W-500, made by Kawaguchi Chemical Industry Ltd).

Furthermore, there are bisphenols such as 4,4'-butylidenebis(3-methyl-6-t-butylphenol) (Antage W-300, made by Kawaguchi Chemical Industry Ltd.), 4,4'-methylenebis(2,6-di-t-butylphenol) (Ionox 220AH, made by Shell Japan Ltd.), 4,4'-bis(2,6-di-t-butylphenol), 2,2-(di-p-hydroxyphenyl)propane (Bisphenol A, made by Shell Japan Ltd.), 2,2-bis(3,5-di-t-butyl-4-hydroxyphenyl)propane, 4,4'-cyclohexylidenebis(2,6-t-butylphenol), hexamethylene glycol bis[3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate] (Irganox L109, made by Ciba Specialty Chemicals Ltd.), triethylene glycol bis[3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionate] (Tominox 917, made by Yoshitomi Fine Chemicals Ltd.), 2,2'-thio-[diethyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate (Irganox L115, made by Ciba Specialty Chemicals Ltd.), 3,9-bis{1,1-dimethyl-2-[3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionyloxy]ethyl}2,4,8,10 - tetraoxaspiro[5,5]undecane (Sumilizer GA80, made by Sumitomo Chemicals), 4,4'-thiobis(3-methyl-6-t-butylphenol) (Antage RC, made by Kawaguchi Chemical Industry Ltd.) and 2,2'-thiobis(4,6-di-t-butyl-resorcinol).

Mention may also be made of polyphenols such as tetrakis[methylene-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate]methane (Irganox L101, made by Ciba Specialty Chemicals Ltd.), 1,1,3-tris(2-methyl-4-hydroxy-5-t-butylphenyl)butane (Yoshinox 930, made by Yoshitomi Fine

Chemicals Ltd.), 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-hydroxybenzyl)benzene (Ionox 330, made by Shell Japan Ltd.), bis-[3,3'-bis-(4'-hydroxy-3'-t-butylphenyl) butyric acid] glycol ester, 2-(3',5'-di-t-butyl-4-hydroxyphenyl) methyl-4-(2'',4''-di-t-butyl-3''-hydroxyphenyl)methyl-6-t-butylphenol and 2,6,-bis(2'-hydroxy-3'-t-butyl-5'-methyl-benzyl)-4-methylphenol, and phenol-aldehyde condensates such as condensates of p-t-butylphenol and formaldehyde and condensates of p-t-butylphenol and acetaldehyde.

As examples of phosphorus-based anti-oxidants mention may be made of triarylphosphites such as triphenylphosphite and tricresylphosphite, trialkylphosphites such as trioctadecylphosphite and tridecylphosphite, and tridodecyltrithiophosphite.

Metal deactivators that can be used together with the composition of this invention include benzotriazole and benzotriazole derivatives which are 4-alkyl-benzotriazoles such as 4-methyl-benzotriazole and 4-ethyl-benzotriazole, 5-alkyl-benzotriazoles such as 5-methyl-benzotriazole and 5-ethyl-benzotriazole, 1-alkyl-benzotriazoles such as 1-dioctylaminomethyl-2,3-benzotriazole and 1-alkyl-tolutriazoles such as 1-dioctylaminomethyl-2,3-tolutriazole, and benzoimidazole and benzoimidazole derivatives which are 2-(alkyldithio)-benzoimidazoles such as 2-(octyldithio)-benzoimidazole, 2-(decyldithio)-benzoimidazole and 2-(dodecyldithio)-benzoimidazole and 2-(alkyldithio)toluimidazoles such as 2-(octyldithio)-toluimidazole, 2-(decyldithio)-toluimidazole and 2-(dodecyldithio)toluimidazole.

Also, mention may be made of indazole, indazole derivatives which are toluindazoles such as 4-alkyl-indazoles and 5-alkyl-indazoles, benzothiazole, and

benzothiazole derivatives which are 2-mercaptobenzothiazole derivatives (Thiolite B-3100, made by Chiyoda Chemical Industries Ltd.), 2-(alkykldithio)benzothiazoles such as 2-(hexyldithio)benzothiazole and 2-(octyldithio)benzothiazole, 2-(alkyldithio)toluthiazoles such as 2-(hexyldithio)toluthiazole and 2-(octyldithio)toluthiazole, 2-(N,N-dialkylydithiocarbamyl)-benzothiazoles such as 2-(N,N-diethyldithiocarbamyl)-benzothiazole, 2-(N,N-dibutyldithiocarbamyl)-benzothiazole and 2-(N,N-dihexyldithiocarbamyl)-benzothiazole, and 2-(N,N-dialkylydithiocarbamyl)-toluthiazoles such as 2-(N,N-diethyldithiocarbamyl)-toluthiazole, 2-(N,N-dibutyldithiocarbamyl)-toluthiazole and 2-(N,N-dihexyldithiocarbamyl)-toluthiazole.

Further, mention may be made of benzooxazole derivates which are 2-(alkyldithio)benzooxazoles such as 2-(octyldithio)benzooxazole, 2-(decyldithio)benzooxazole and 2-(dodecyldithio)benzooxazole or which are 2-(alkyldithio)toluoxazoles such as 2-(octyldithio)toluoxazole, 2-(decyldithio)toluoxazole and 2-(dodecyldithio)toluoxazole, thiadiazole derivatives which are 2,5-bis(alkyldithio)-1,3,4-thiadiazoles 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-thiadiazoles 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-thiadiazoles

such as 2-N,N-dibutyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole and 2-N,N-dioctyldithiocarbamyl-5-mercapto-1,3,4-thiadiazole, and triazole derivates which are, for example, 1-alkyl-2,4-triazoles such as 1-di-octylaminomethyl-2,4-triazole.

These metal deactivators may be used in the lubricating oil composition singly or in mixtures in an amount in the range of from 0.01 to 0.5% by mass.

It is also possible to add phosphorus compounds to the lubricating oil composition of this invention in order to impart anti-wear properties and extreme-pressure properties. As examples of phosphorus compounds suitable for this invention, mention may be made of phosphate esters, acidic phosphate esters, amine salts of acidic phosphate esters, chlorinated phosphate esters, phosphite esters, phosphorothionates, zinc dithiophosphates, esters of dithiophosphates and alkanols or polyether-type alcohols or derivatives thereof, phosphorus-containing carboxylic acids and phosphorus-containing carboxylic acid esters.

These phosphorus compounds may be used singly or in mixtures in an amount in the range of from 0.01 to 2% by mass in the lubricating oil composition.

As examples of the aforementioned phosphate esters, mention may be made of 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, tris(iso-propylphenyl)phosphate, triaryl phosphate, tricresyl

phosphate, trixylenyl phosphate, cresyldiphenyl phosphate and xylenyldiphenyl phosphate.

As specific examples of the aforementioned acidic phosphate esters, mention may be made of monobutyl acid phosphate, monopentyl acid phosphate, monohexyl acid phosphate, monoheptyl acid phosphate, monooctyl acid phosphate, monononyl acid phosphate, monodecyl acid phosphate, monoundecyl acid phosphate, monododecyl acid phosphate, monotridecyl acid phosphate, monotetradecyl acid phosphate, monopentadecyl acid phosphate, monohexadecyl acid phosphate, monoheptadecyl acid phosphate, monooctadecyl acid phosphate, monooleyl acid phosphate, dibutyl acid phosphate, dipentyl acid phosphate, dihexyl acid phosphate, diheptyl acid phosphate, dioctyl acid phosphate, dinonyl acid phosphate, didecyl acid phosphate, diundecyl acid phosphate, didodecyl acid phosphate, ditridecyl acid phosphate, ditetradecyl acid phosphate, dipentadecyl acid phosphate, dihexadecyl acid phosphate, diheptadecyl acid phosphate, dioctadecyl acid phosphate and dioleyl acid phosphate.

As examples of the aforementioned amine salts of acidic phosphate esters, mention may be made of the methylamine, ethylamine, propylamine, butylamine, pentylamine, hexylamine, heptylamine, octylamine, dimethylamine, diethylamine, dipropylamine, dibutylamine, dipentylamine, dihexylamine, diheptylamine, dioctylamine, trimethylamine, triethylamine, tripropylamine, tributylamine, tripentylamine, trihexylamine, triheptylamine and trioctylamine salts of the previously mentioned acidic phosphate esters.

As examples of the aforementioned phosphite esters, mention may be made of dibutyl phosphite, dipentyl

phosphite, dihexyl phosphite, diheptyl phosphite, dioctyl phosphite, dinonyl phosphite, didecyl phosphite, diundecyl phosphite, didodecyl phosphite, dioleyl phosphite, diphenyl phosphite, dicresyl phosphite, tributyl phosphite, tripentyl phosphite, trihexyl phosphite, triheptyl phosphite, trioctyl phosphite, trinonyl phosphite, tridecyl phosphite, triundecyl phosphite, tridodecyl phosphite, trioleyl phosphite, triphenyl phosphite and tricresyl phosphite.

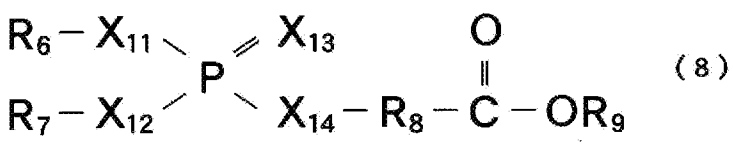
As examples of the aforementioned phosphorothionates, mention may be made specifically of tributyl phosphorothionate, tripentyl phosphorothionate, trihexyl phosphorothionate, triheptyl phosphorothionate, trioctyl phosphorothionate, trinonyl phosphorothionate, tridecyl phosphorothionate, triundecyl phosphorothionate, tridodecyl phosphorothionate, tritridecyl phosphorothionate, tritetradecyl phosphorothionate, tripentadecyl phosphorothionate, trihexadecyl phosphorothionate, triheptadecyl phosphorothionate, trioctadecyl phosphorothionate, trioleyl phosphorothionate, triphenyl phosphorothionate, tricresyl phosphorothionate, trixylenyl phosphorothionate, cresyldiphenyl phosphorothionate, xylenyldiphenyl phosphorothionate, tris(n-propylphenyl) phosphorothionate, tris(isopropylphenyl) phosphorothionate, tris(n-butylphenyl) phosphorothionate, tris(isobutylphenyl) phosphorothionate, tris(s-butylphenyl) phosphorothionate and tris(t-butylphenyl) phosphorothionate. Mixtures of these may also be used.

As examples of the aforementioned zinc dithiophosphates, mention may be made in general of zinc dialkyl dithiophosphates, zinc diaryl dithiophosphates and zinc arylalkyl dithiophosphates. For example, zinc

dialkyl dithiophosphates where the alkyl groups of the zinc dialkyl dithiophosphates have primary or secondary alkyl groups having from 3 to 22 carbon atoms or alkylaryl groups substituted with alkyl groups having from 3 to 18 carbon atoms may be used.

As specific examples of zinc dialkyl dithiophosphates, mention may be made of zinc dipropyl dithiophosphate, zinc dibutyl dithiophosphate, zinc dipentyl dithiophosphate, zinc dihexyl dithiophosphate, zinc diisopentyl dithiophosphate, zinc diethylhexyl dithiophosphate, zinc dioctyl dithiophosphate, zinc dinonyl dithiophosphate, zinc didecyl dithiophosphate, zinc didodecyl dithiophosphate, zinc dipropylphenyl dithiophosphate, zinc dipentylphenyl dithiophosphate, zinc dipropylmethylphenyl dithiophosphate, zinc dinonylphenyl dithiophosphate and zinc didodecylphenyl dithiophosphate.

Phosphorus-containing carboxylic compounds such as phosphorus-containing carboxylic acids and their acid esters should include both a carboxyl group and a phosphorus atom in the same molecule. Their structure is not specially limited but normally, from the standpoint of extreme pressure properties and thermal and oxidative stability, phosphorylated carboxylic acids or phosphorylated carboxylic acid esters are preferred. As examples of phosphorylated carboxylic acids or phosphorylated carboxylic acid esters, mention may be made of compounds as exemplified by the following general formula (8):

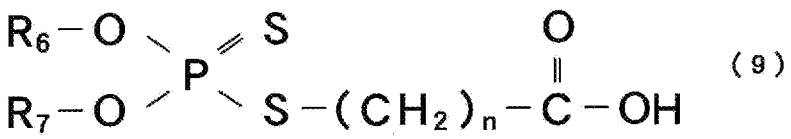


(8)

In the aforementioned general formula (8), R_6 and R_7 may be the same or different and each denotes a hydrogen atom or a hydrocarbon group having from 1 to 30 carbon atoms. R_8 denotes an alkylene group having from 1 to 20 carbon atoms. R_9 denotes a hydrogen atom or a hydrocarbon group having from 1 to 30 carbon atoms. X_{11}, X_{12}, X_{13} and X_{14} may be the same or different and each denotes an oxygen atom or a sulphur atom.

As examples of the hydrocarbon groups having from 1 to 30 carbon atoms in R_6 and R_7 in the aforementioned general formula (8), mention may be made of alkyl groups, alkenyl groups, aryl group, alkylaryl groups and arylalkyl groups.

β-dithiophosphorylated propionic acids, which are useful examples of the aforementioned β-dithiophosphorylated carboxylic acids, have the structure shown in the following general formula (9):



(9)

As a specific example of these β-dithiophosphorylated propionic acids, mention may be made of 3-(di-isobutoxy-thiophosphorylsulphanyl)-2-methyl propionic acid.

The amount of phosphorus-containing carboxylic acid compound in the present lubricating oil composition is not specially limited, but is preferably in the range of from 0.001 to 1% by mass and more preferably in the range of from 0.002 to 0.5% by mass in the lubricating oil composition. If the amount of phosphorus-containing carboxylic acid compound is less than the above-mentioned

lower limit, there will be a likelihood of satisfactory lubricating qualities not being obtained. On the other hand, even if the above-mentioned upper limit is exceeded, it is likely that an effect in improving the lubrication properties matching the amount added will not be obtained. Furthermore, there is a risk that the thermal and oxidative stability and the hydrolytic stability will be reduced, which is not desirable.

The amount of the compound where R_9 is a hydrogen atom in a phosphorylated carboxylic acid as expressed by the aforementioned general formula (8) is in the range of 0.001 to 0.1% by mass, preferably in the range of from 0.002 to 0.08% by mass, more preferably in the range of from 0.003 to 0.07% by mass, still more preferably in the range of from 0.004 to 0.06% by mass, and even more preferably in the range of from 0.005 to 0.05% by mass.

In order to improve the low-temperature flow characteristics and viscosity characteristics, pour-point depressants and viscosity-index improvers may also be added to the lubricating oil composition of this invention.

As examples of viscosity-index improvers mention may be made of non-dispersant type viscosity-index improvers such as polymethacrylates and olefin polymers such as ethylene-propylene copolymers, styrene-diene copolymers, polyisobutylene and polystyrene, and dispersant type viscosity-index improvers where nitrogen-containing monomers have been copolymerised with these. They may be used in an amount in the range of from 0.05 - 20% by mass in the lubricating oil composition.

As examples of pour-point depressants mention may be made of polymethacrylate-based polymers.They may be used in an amount in the range of from 0.01 to 5% by mass in

the lubricating oil composition.

Defoaming agents may also be added in order to impart defoaming characteristics to the lubricating oil composition of this invention. As examples of such defoaming agents suitable for this invention, mention may be made of organosilicates such as dimethylpolysiloxane, diethylsilicate and fluorosilicone, and non-silicone type defoaming agents such as polyalkylacrylates.They may be used singly or in mixtures in an amount in the range of from 0.0001 to 0.1% by mass in the lubricating oil composition.

As examples of demulsifiers suitable for this invention, mention may be made of those in the known art normally used as additives for lubricating oils. They may be used in an amount in the range of from 0.0005 to 0.5% by mass in the lubricating oil composition.

Examples

The invention is explained in specific detail below by means of examples and comparative examples, but the invention is not limited to only these examples.

For preparation of the examples and comparative examples, the compositions and materials mentioned below were used.

1. Base oils

(1-1) Base Oil 1: A paraffinic mineral oil obtained by use of a suitable combination of refining processes such as hydrocracking and dewaxing in respect of a lubricating oil fraction obtained by atmospheric distillation of crude oil, and classified as Group II (Gp 2) according to the API (American Petroleum Institute) base oil classification. (Characteristics: kinetic viscosity at 100°C, 5.35 mm^2/s; kinetic viscosity at 40°C, 31.4 mm^2/s; viscosity index, 103; sulphur content

(as converted to elemental sulphur), less than 10 ppm; nitrogen content (as converted to elemental nitrogen), less than 1 ppm; aniline point, 110°C; density at 15°C: 0.864; density at 20°C: 0.860; refractive index at 20°C: 1.472; molecular weight (ASTM D2502): 411; ring-analysis paraffin content according to the method of ASTM D3238, 62%; naphthene content according to the method of ASTM D3238, 38%; aromatic content according to the method of ASTM D3238, less than 1%; initial boiling point temperature according to gas chromatography distillation by the method of ASTM D5480, 312°C)

(1-2) Base Oil 2: A paraffinic mineral oil obtained by use of a suitable combination of refining processes such as hydrocracking and dewaxing in respect of a lubricating oil fraction obtained by atmospheric distillation of crude oil, and classified as Group III (Gp 3) according to the API (American Petroleum Institute) base oil classification. (Characteristics: kinetic viscosity at 100°C, 6.57 mm^2/s; kinetic viscosity at 40°C, 37.5 mm^2/s; viscosity index, 130; sulphur content (as converted to elemental sulphur), less than 10 ppm; nitrogen content (as converted to elemental nitrogen), less than 1 ppm; aniline point, 123°C; density at 15°C: 0.844; density at 20°C: 0.841; refractive index at 20°C: 1.465; molecular weight (ASTM D2502): 479; ring-analysis paraffin content according to the method of ASTM D3238, 79%; naphthene content according to the method of ASTM D3238, 22%; aromatic content according to the method of ASTM D3238, less than 1%; polynuclear aromatic content according to the method of IP 346, 0.2%); initial boiling point temperature according to gas chromatography distillation by the method of ASTM D5480: 306°C.

(1-3) Base Oil 3: A GTL base oil synthesised by the Fischer-Tropsch method, and classified as Group III (Gp 3) according to the API (American Petroleum Institute) base oil classification. (Characteristics: kinetic viscosity at 100°C, 5.10 mm^2/s; kinetic viscosity at 40°C, 23.5 mm^2/s; viscosity index, 153; 15°C density, 0.821; sulphur content (as converted to elemental sulphur), less than 10 ppm; nitrogen content (as converted to elemental nitrogen), less than 1 ppm; aniline point: 126°C; density at 15°C: 0.821; density at 20°C: 0.817; refractice index at 20°C: 1.456; molecular weight (ASTM D2502): 447; ring-analysis paraffin content according to the method of ASTM D3238: 95%, aromatic content according to the method of ASTM D3238: less than 1%, initial boiling point temperature according to gas chromatography distillation by the method of ASTM D5480: 365°C)

(1-4) Base Oil 4: A synthetic oil being a poly-α-olefin (PAO) with the general name PAO6, and classified as Group IV (Gp 4) according to the API (American Petroleum Institute) base oil classification. (Characteristics: kinetic viscosity at 100°C, 5.89 mm^2/s; kinetic viscosity at 40°C, 31.2 mm^2/s; viscosity index, 135; 15°C density, 0.827; sulphur content (as converted to elemental sulphur), less than 10 ppm; nitrogen content (as converted to elemental nitrogen), less than 1 ppm; aniline point, 128°C; 15°C density: 0.827; 20°C density: 1.460; ring-analysis aromatic content according to the method of ASTM D3238, less than 1%; initial boiling point temperature according to gas chromatography distillation by the method of ASTM D5480, 403°C)

(1-5) Base Oil 5: A paraffinic mineral oil obtained by use of a suitable combination of refining

processes such as dewaxing in respect of a lubricating oil fraction obtained by atmospheric distillation of crude oil, and classified as Group I (Gp 1) according to the API (American Petroleum Institute) base oil classification. (Characteristics: kinetic viscosity at 100°C, 4.60 mm^2/s; kinetic viscosity at 40°C, 24.6 mm^2/s; viscosity index, 101; 15°C density, 0.866; sulphur content (as converted to elemental sulphur), 4500 ppm by mass; nitrogen content (as converted to elemental nitrogen), 20 ppm by mass; ring-analysis paraffin content according to the method of ASTM D3238, 66%; naphthene content according to the method of ASTM D3238, 31%; aromatic content according to the method of ASTM D3238, 3%; aniline point, 99°C; polynuclear aromatic content according to the method of IP 346, 0.8%; initial boiling point temperature according to gas chromatography distillation by the method of ASTM D5480, 331°C)

2. Additives

(2-1) Additive A1: Succinic acid derivative: tetraisopropenyl succinic acid, 1,2-propanediol half ester (acid number by the method of JIS K2501: 160 mgKOH/g)

(2-2) Additive A2: Succinic acid derivative: tetraisopropenyl succinic acid, 1,3-propanediol half ester (acid number by the method of JIS K2501: 160 mgKOH/g)

(2-3) Additive A3: Succinic acid derivative: RheinChemie RC4802 (acid number by the method of ASTM D3739: 55mgKOH/g)

(2-4) Additive B1: Epoxidised rapeseed fatty acid 2 ethylhexyl ester

(2-5) Additive B2: Epoxidised rapeseed fatty acid isobutyl ester

(2-6) Additive B3: Epoxidised soybean oil

(2-7) Additive C1: Coconut amine (the main constituent being dodecylamine)(base number by the method of JIS K2501: 440 mgKOH/g)

(2-8) Additive C2: diethanol amine: N-alkenyl diethanolamine (the main constituent being N-dodecyl diethanolamine), tertiary amine compound (base number by the method of JIS K2501: 160 mgKOH/g)

(2-9) Additive C3: N-alkenyl diethanolamine (the main constituent being N-oleyl diethanolamine), teriary amine compound (base number by the method of JIS K2501: 160 mgKOH/g)

(2-10) Additive D1: Polyamine amide (the main constituent being isostearic acid triethylenetetramide)(base number by the method of JIS K2501: 7 mgKOH/g)

(2-11) Additive D2: Oleylamide

(2-12) Additive E1: Trimethylolpropane monooleate

(2-13) Additive E2: Pentaerythritol monooleate

(2-14) Additive E3: glycerol monoisostearate (hydroxyl number by the method of JIS K0070: 313 mgKOH/g)

Examples 1 to 23 and Comparative Examples 1 to 9

Using the aforementioned compositions and materials, the lubricating oil compositions of Examples 1 to 23 and Comparative Examples 1 to 9 were prepared having constituent amounts as shown in Tables 1 to 7.

Tests

The following tests were carried out on the lubricating oil compositions of the aforementioned Examples 1 to 23 and Comparative Examples 1 to 9 in order to observe their performance.

Rust Prevention Tests

Following JIS K2510, 300 ml of test oil was taken

and put in a container disposed in a constant-temperature bath. It was agitated at a speed of 1000 turns per minute. When the temperature reached 60°C, an iron test specimen was inserted into the oil being tested and 30 ml of artificial sea water was also added. Keeping the temperature at 60°C, agitation was continued for 24 hours. Then the specimen was removed and assessed visually for occurrence of any rust.

The evaluation of the tests was made according to the following criteria:

No rust: Ø (Pass)

Rust is observed x (Fail)

Thermal Stability Test

In accordance with Thermal Stability Test Procedure 'A' of Cincinnati Milacron Inc., 200 ml of the oil being tested was taken and put in a container disposed inside a constant-temperature bath, and left there for 168 hours at 135°C in the joint presence of a copper catalyst and an iron catalyst. Then, after cooling to room temperature, the sludge was gathered by a 5-micron filter and the amount of sludge generated was weighed. The figures in the tables are the amount of sludge per 200 ml of test oil (mg/200 ml).

The evaluation of the tests was made according to the following criteria:

Amount of sludge generated less than 2.5 mg/200 ml Ø (Pass)

Amount of sludge generated 2.5 mg/200 ml or more X (Fail)

Pendulum Test, Friction Coefficient

The friction coefficient was measured using a Masuda pendulum-type oiliness tester manufactured by Shinko Machine Manufacturing Co. Ltd. In this test the oil being

tested is supplied to the friction portion of the pendulum fulcrum, the pendulum is made to move, and the friction coefficient is obtained from the reduction in oscillations. Tests were carried out for Examples 9 to 23 and Comparative Examples 1 to 9.

The evaluation of the tests was made according to the following criteria:

Friction coefficient 0.135 or less (Excellent)	Ø
Friction coefficient 0.136 to less than 0.150 (Good)	O
Friction coefficient 0.150 or more (Not acceptable)	X

Test Results

The results of the tests are shown in Tables 1 to 7.

Discussion

As is clear from the results in Table 1, the instances of using a Group II base oil combined with succinic acid derivatives (Additive A1/A2) and epoxy compounds (Additive B1/B2) as shown in Examples 1 to 3 passed (Ø) in the artificial sea-water rust-prevention test with no occurrence of rust and also passed (Ø) as regards amount of sludge, with little sludge being generated.

Also, as shown in Examples 4 to 8 in Table 2, each of the lubricating oil compositions using a Group III base oil (Base Oil 2), a GTL (Base Oil 3) or a PAO (Base Oil 4) as the base oil passed (Ø) with no occurrence of rust and also passed (Ø) as regards amount of sludge, with little sludge being generated.

The instances of Examples 9 to 12 shown in Table 3 using a Group II base oil (Base Oil 1), a Group III base oil (Base Oil 2), a GTL (Base Oil 3) or a PAO (Base Oil

4) as the base oil combined with succinic acid derivatives (Additive A1/A2), epoxy compounds (Additive B1/B2) and an amine compound (Additive C1), passed (Ø) in the artificial sea-water rust-prevention test with no occurrence of rust, also passed (Ø) as regards amount of sludge, with little sludge being generated, and further came up as Good in Examples 9 and 12, or Excellent (Ø) in the case of Examples 10 and 11, in having a low friction coefficient.

Examples 13 and 14, comprising a base oil (Base Oil 1), a succinate derivative (Additive A3), an epoxide (Additive B2) and an amine (Additive C1 and/or C2) passed (Ø) in the artificial sea-water rust-prevention test with no occurrence of rust, also passed (Ø) as regards amount of sludge, with little sludge being generated, and further came up as Excellent (Ø) in having a low friction coefficient.

Examples 15 to 17 shown in Table 4 used either a Group II base oil (Base Oil 1) or a GTL (Base Oil 3) as the base oil combined with a succinic acid derivative (Additive A), an epoxy compound (Additive B) and amide compounds (Additive D1/D2), and passed (Ø) in the artificial sea-water rust-prevention test with no occurrence of rust, also passed (Ø) as regards amount of sludge, with little sludge being generated, and further came up as Good, or Excellent (Ø) in the case of Examples 16 and 17, in having a low friction coefficient.

Examples 18 and 19 shown in Table 4 used either a Group II base oil (Base Oil 1) or a GTL (Base Oil 3) as the base oil combined with a succinic acid derivative (Additive A1), an epoxy compound (Additive B1) and polyhydric alcohol esters (Additive E1 or E2), and passed (Ø) in the artificial sea-water rust-prevention test with

no occurrence of rust, also passed (Ø) as regards amount of sludge, with little sludge being generated, and both came up as Excellent (Ø) in having a low friction coefficient. Also, Example 20 used a Group II base oil (Base Oil 1) as the base oil combined with a succinic acid derivative (Additive A1), an epoxy compound (Additive B1), an amine compound (Additive C1) and an amide compound (Additive D1), and passed (Ø) in the rust-prevention test with no occurrence of rust, also passed (Ø) as regards amount of sludge, and also came up as Excellent (Ø) in having a low friction coefficient.

Examples 21-23 shown in Table 5 used a Group II base oil (Base Oil 1) as the base oil combined with a succinic acid derivative (Additive A2/A3), an epoxy compound (Additive B1/B2) an amine (Additive C1 and C3 or Additive C1 and C2) and a polyol ester (Additive E3), and passed (Ø) in the artificial sea-water rust-prevention test with no occurrence of rust, also passed (Ø) as regards amount of sludge, with little sludge being generated, and came up as Excellent (Ø) in having a low friction coefficient.

In contrast, Comparative Examples 1 to 8 used a Group II base oil (Base Oil 1) as the base oil, but in the case of the Group II base oil (Base Oil 1) alone in Comparative Example 1, it passed (Ø) as regards amount of sludge, but failed in both the rust-prevention test and as regards friction coefficient. In the cases of addition of a succinic acid derivative (Additive A) alone, in Comparative Examples 2 and 3, they passed (Ø) the rust-prevention test but failed (X) as regards amount of sludge and friction coefficient.

Comparative Examples 4 and 5 were examples of addition of an epoxy compound (Additive B) alone. Comparative Example 4 passed (Ø) as regards sludge amount

but failed (X) in the rust-prevention test and as regards friction coefficient. In the case of Comparative Example 5, the value for the amount of sludge was too high and so measurement of the friction coefficient was omitted.

Comparative Example 6 was an example of addition of an amide compound (Additive D1) alone. It passed (Ø) as regards sludge amount and friction coefficient but failed (X) in the rust-prevention test. Comparative Example 7 was an example of addition of an amide compound (Additive D2) alone. It passed (Ø) as regards the friction coefficient but failed (X) in the rust-prevention test and as regards amount of sludge.

Comparative Example 8 was an example of addition of a polyhydric alcohol ester (Additive E2) alone. It passed (Ø) in the rust-prevention test, and was Good (O) as regards the friction coefficient, but it failed (X) as regards amount of sludge. Comparative Example 9 used a Group I base oil (Base Oil 5) as the base oil combined with a succinic acid derivative (Additive A) and an epoxy compound (Additive B), but although it passed (Ø) in the rust-prevention test, it failed (X) as regards amount of sludge. Measurement of the friction coefficient was also omitted in the case of Comparative Example 9 because the value for the amount of sludge was too high.

As discussed above, excellent results compared with the comparative examples were obtained for each of the examples of the present invention. It was evident that they were to be preferred as lubricating oil compositions in this invention.

Table 1

		Ex. 1 mass %	Ex. 2 mass %	Ex. 3 mass %
Composition	Base Oil 1, Gp 2	99.4	99.4	99.4
	Additive A1 Succinic acid derivative	0.1		0.1
	Additive A2 Succinic acid derivative		0.1	
	Additive B1 Epoxidised rapeseed Fatty acid 2-ethylhexyl ester	0.5		
	Additive B2 Epoxidised rapeseed fatty acid isobutyl ester		0.5	0.5
Test Results	Rust (artificial sea water)	Pass Ø	Pass Ø	Pass Ø
	Sludge (mg/200 ml)	2.2 Ø	1.7 Ø	1.2 Ø

Table 2

		Ex. 4 mass%	Ex. 5 mass%	Ex. 6 mass%	Ex. 7 mass%	Ex. 8 mass%
Composition	Base Oil 2, Gp 3	99.4				
	Base Oil 3, GTL		99.4	99.4	99.4	
	Base Oil 4, PAO					99.4
	Additive A1 Succinic acid derivative	0.1	0.1		0.1	0.1
	Additive A2 Succinic acid derivative			0.1		
	Additive B1 Epoxidised rapeseed fatty acid 2-ethylhexyl ester	0.5		0.5	0.5	0.5
	Additive B2 Epoxidised rapeseed fatty acid isobutyl ester		0.5			
Test Results	Rust (artificial sea water)	Pass Ø	Pass Ø	Pass Ø	Pass Ø	Pass Ø
	Sludge (mg/200 ml)	0.1 Ø	1.8 Ø	1.5 Ø	0.6 Ø	0.8 Ø

Table 3

		Ex. 9 mass%	Ex. 10 mass%	Ex. 11 mass%	Ex. 12 mass%	Ex. 13 mass%	Ex. 14 mass %
Composition	Base Oil 1, Gp 2	99.2				99.2	99.2
	Base Oil 2, Gp 3		99.2				
	Base Oil 3, GTL			99.2			
	Base Oil 4, PAO				99.2		
	Additive A1 Succinic acid derivative		0.1	0.1	0.1		
	Additive A2 Succinic acid derivative	0.1					
	Additive A3 Succinic acid derivative					0.1	0.1
	Additive B1 Epoxidised rapeseed fatty acid 2-ethylhexyl ester		0.5	0.5	0.5		
	Additive B2 Epoxidised Rapeseed Fatty acid isobutyl ester	0.5				0.5	0.5
	Additive C1 Coconut amine	0.2	0.2	0.2	0.2	0.15	0.1
	Additive C2 Diethanol amine					0.05	0.1
Test Results	Rust (artificial sea water)	Pass Ø	Pass Ø	Pass Ø	Pass Ø	Pass Ø	Pass Ø
	Sludge (mg/200 ml)	1.4 Ø	2.0 Ø	2.1 Ø	1.1 Ø	0.0 Ø	0.0 Ø
	Pendulum test Friction coefficient	0.138 O	0.133 Ø	0.121 Ø	0.143 O	0.116 Ø	0.112 Ø

Table 4

		Ex. 15 mass%	Ex. 16 mass%	Ex. 17 mass%	Ex. 18 Mass %	Ex. 19 Mass%	Ex.20 Mass%
Composition	Base Oil 1, Gp 2	99.3		99.3	99.2		99.1
	Base Oil 3, GTL		99.3			99.2	
	Additive A1 Succinic acid derivative	0.1	0.1	0.1	0.1	0.1	0.1
	Additive B1 Epoxidised rapeseed Fatty acid 2 ethylhexyl ester	0.5	0.5	0.5	0.5	0.5	0.5
	Additive C1 coconut amide						0.2
	Additive D1 Polyamine amide	0.1	0.1				0.1
	Additive D2 Oleylamide			0.1			
	Additive E1 trimethylolpropanemonooleate				0.2		
	Additive E2 pentaerythritolmonooleate					0.2	
Test Results	Rust (artificial sea water)	Pass Ø	Pass Ø	Pass Ø	Pass Ø	Pass Ø	Pass Ø
	Sludge (mg/200 ml)	0.2 Ø	0.5 Ø	0.3 Ø	1.6 Ø	2.0 Ø	0.3 Ø
	Pendulum test Friction coefficient	0.138 0	0.114 Ø	0.125 Ø	0.129 Ø	0.109 Ø	0.114 Ø

Table 5

		Ex. 21 mass%	Ex. 22 mass%	Ex. 23 mass%
Composition	Base Oil 1, Gp 2	99.0	99.0	99.0
	Additive A2 suucinic acid derivative	0.1	0.1	
	Additive A3 Succinic acid derivative			0.1
	Additive B1 Epoxidised rapeseed fatty acid 2-ethylhexyl ester			0.5
	Additive B2 Epoxidised rapeseed fatty acid iso-butyl ester	0.5	0.5	
	Additive C1 Coconut amine	0.15	0.1	0.15
	Additive C2 Diethanolamine			0.05
	Additive C3 Diethanolamine	0.05	0.1	
	Additive E3 glycerol monoisostearate	0.2	0.2	0.2
Test Results	Rust (artificial sea water)	Pass Ø	Pass Ø	Pass Ø
	Sludge (mg/200 ml)	0.9 Ø	1.2 Ø	0.1 Ø
	Pendulum test Friction coefficient	0.125 Ø	0.113 Ø	0.123 Ø

Table 6

		Comp. Ex. 1 mass%	Comp. Ex. 2 mass%	Comp. Ex. 3 mass%	Comp. Ex. 4 mass%	Comp. Ex. 5 mass%
Composition	Base Oil 1, Gp 2	100	99.9	99.9	99.5	99.5
	Additive A1 Succinic acid derivative		0.1			
	Additive A2 Succinic acid derivative			0.1		
	Additive B2 Epoxidised rapeseed fatty acid isobutyl ester				0.5	
	Additive B3 Epoxidised soybean oil					0.5
Test Results	Rust (artificial sea water)	Fail X	Pass Ø	Pass Ø	Fail X	Fail X
	Sludge (mg/200 ml)	0.6 Ø	3.1 X	2.8 X	0.8 Ø	434 X
	Pendulum test Friction coefficient	0.307 X	0.157 X	0.159 X	0.294 X	------

Table 7

		Comp. Ex. 6 mass%	Comp. Ex. 7 mass%	Comp. Ex. 8 mass%	Comp. Ex. 9 mass%
Composition	Base Oil 1, Gp 2	99.9	99.9	99.8	
	Base Oil 5, Gp 1				99.4
	Additive A1 Succinic acid derivative				0.1
	Additive B1 Epoxidised rapeseed fatty acid 2 ethylhexyl ester				0.5
	Additive D1 Polyamine amide	0.1			
	Additive D2 Oleylamide		0.1		
	Additive E2 Pentaerythritol oleate			0.2	
Test Results	Rust (artificial sea water)	Fail X	Fail X	Pass Ø	Pass Ø
	Sludge (mg/200 ml)	0.4 Ø	10.5 X	10.8 X	35.7 X
	Pendulum test Friction coefficient	0.120 Ø	0.134 Ø	0.146 O	-------

C L A I M S

1. Lubricating oil composition comprising a succinic acid derivative and an epoxy compound as additives, and a base oil selected from a mineral oil, a synthetic oil, and mixtures thereof, wherein the base oil has a sulphur content of not more than 0.3% by mass.
2. Lubricating oil composition according to Claim 1 wherein the acid number of the aforementioned succinic acid derivative is in the range of from 10 to 300 mgKOH/g (JIS K2501).
3. Lubricating oil composition according to Claim 1 or 2 wherein the aforementioned epoxy compound is an epoxidised fatty acid ester.
4. Lubricating oil composition according to any of Claims 1 to 3 wherein the amount of the aforementioned succinic acid derivative contained in the lubricating oil composition is in the range of from 0.001 to 0.5% by mass and the amount of the epoxy compound is in the range of from 0.01 to 5% by mass.
5. Lubricating oil composition according to any of Claims 1 to 4 additionally comprising at least one amine compound, amide compound or polyhydric alcohol ester as an additive.
6. Lubricating oil composition according to any of Claims 1 to 5 wherein the aforementioned base oil is a GTL.
7. Lubricating oil composition according to any of Claims 1 to 5 wherein the aforementioned base oil is a poly-α-olefin.

8. Use of a lubricating composition according to any of Claims 1 to 7 for rust prevention and/or for reducing sludge.

9. Use of a lubricating composition according to any of Claims 1 to 7 for friction reduction.