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(54) LUBRICANT COMPOSITION

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COMPOSITION LUBRIFIANTE

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(Cont. next page)

- **Kathleen O?leary Havelka ET AL: "From Biorefinery to Performance Technology: Transforming Renewable Olefinic Building Blocks into Lubricants and Other High-Value Products" In: "Chemistry, Process Design, and Safety for the Nitration Industry /ACS /Symposium Series", 1 January 2015 (2015-01-01), American Chemical Society/Oxford University Press, US, XP055574787, ISSN: 0097-6156 vol. 1192, pages 201-222, DOI: 10.1021/bk-2015-1192.ch013,**

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Description

[0001] This invention relates to a lubricant oil composition and a method of lubricating a gearbox or operating an apparatus having a gearbox wherein the gearbox comprises a rolling element.

BACKGROUND

[0002] Industrial manufacturing facilities and processes use apparatus and robots for manufacturing processes, which have gearboxes requiring lubrication. Depending upon manufacturer design requirements, gearboxes can be lubricated with grease or lubricant oils. For oil-lubricated gearboxes, the demands for lubricants are particular and include sludge-free and leak-free performance for an extended period of time with a target of 20,000 hours, particularly in robot gearboxes and especially in the automotive sector.

[0003] Commercial offerings of oils for robot gearboxes tend to suffer from a number of disadvantages, which mean that they tend not to be capable of meeting the industry requirement of 20,000 hours of uninterrupted operation.

[0004] Such disadvantages include poor elastomer compatibility which results in degradation of elastomer forming seals in gearboxes as well as characteristics which result in wear of metal gear components. This can result in leaks of oil from the gearbox which, in many robot applications are problematic and in car manufacture, especially where cleanliness is critical, can be considered catastrophic failures.

[0005] Whilst mineral oil-based lubricant formulations are used, there is increasing demand for synthetic oil-based formulations to meet longevity requirements. Synthetic oils having a poly-alpha-olefin base oil have the potential for greater longevity, but suffer from poorer solubility of additive components.

[0006] Gear boxes for manufacturing apparatus such as robots, as well as for wind turbines, also have rolling elements within them that have a different set of wear and performance requirements to other gearboxes.

[0007] WO 2016/124293 A1 discloses the use of an oil-soluble mono-, di-, or tri-glyceride of at least one hydroxy polycarboxylic acid, or a derivative thereof, as an anti-camshaft-wear additive in a non-aqueous lubricant composition and/or in a fuel composition.

[0008] There is thus a need for a synthetic gear oil formulation that provides stability and longevity, is compatible with seal elastomers, has effective anti- wear properties, particularly in systems with rolling elements, is not prone to sludge formation and has excellent performance characteristics. The present inventor has developed compositions that addresses one or more of the above problems.

SUMMARY OF INVENTION

[0009] According to a first aspect of the invention, there is provided a lubricant composition suitable for use as a lubricant for gearboxes comprising a rolling element, comprising: a base oil composition of lubricating viscosity; and an additive composition comprising a molybdenum dialkyldithiocarbamate and an organic friction modifier selected from an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof, which lubricant composition has no more than 0.1% by weight of molybdenum dithiophosphate.

[0010] Also disclosed herein but not encompassed within the present claims is an additive composition for use in a lubricant composition defined above, the additive composition comprising a molybdenum dialkyldithiocarbamate and an organic friction modifier such as an oil- soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or a derivative thereof.

[0011] In a lubricant composition defined above, the base oil composition may comprise a functionally modified poly-alpha-olefin, a poly-alpha-olefin and optionally an additive carrier.

[0012] In a second aspect of the invention, there is provided a synthetic gear oil composition suitable for use as a lubricant for gearboxes comprising a rolling element, comprising: a base oil composition comprising a modified poly alpha olefin; and an additive composition comprising a molybdenum dialkyldithiocarbamate and an organic friction modifier selected from an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or ester derivative thereof.

[0013] In a third aspect of the invention, there is provided a use of a lubricant or gear oil composition as defined above as a lubricant for gearboxes comprising a rolling element.

[0014] Disclosed herein but not encompassed within the present claims is a kit for manufacture of a lubricant, the kit comprising a base oil composition optionally as defined above an additive pack or additive concentrate optionally having the additive composition as defined above.

[0015] In a fourth aspect of the invention, there is provided a method of lubricating a gearbox comprising a rolling element, the method comprising supplying to a gearbox comprising a rolling element an oil of lubricating viscosity having the lubricating composition as defined above.

[0016] In a fifth aspect of the invention, there is provided a method of operating an apparatus having a gearbox comprising a rolling element, the method comprising supplying to the gearbox a lubricating oil of lubricating viscosity having a composition as defined above.

DETAILED DESCRIPTION

[0017] The invention, according to a first aspect is directed to a lubricant composition suitable for use as a lubricant for gearboxes comprising a rolling element. The lubricant composition comprises a base oil composition and an additive composition. The base oil composition should be such to provide a lubricating viscosity or the lubricating viscosity once the additive composition is added. The base oil composition makes up the major part of the lubricant composition, by which it is meant more than 50% by weight. The additive composition comprises a molybdenum dialkyldithiocarbamate and an organic friction modifier which is an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof.

[0018] The lubricant composition of the present invention finds particular application as a lubricant composition for robotics and robotic gearboxes, industrial gears and wind turbine gears and especially for gearboxes having a rolling element (such as a spherical bearing or a cylindrical bearing). The present invention addresses a particular problem concerning lubricants in such applications, in particular the need for longevity, good elastomer compatibility and good anti-wear properties. Embodiments of the invention also demonstrate excellent protection against leaks and sludge.

[0019] Any suitable molybdenum dialkyldithiocarbamate may be used (including dinuclear and trinuclear molybdenum species).

[0020] The molybdenum dialkyldithiocarbamate may be provided in an amount, in terms of molybdenum, of from 100 to 5000 ppm, preferably from 500 to 3000 ppm and more preferably from 750 to 1500 ppm. In one embodiment, molybdenum dialkyldithiocarbamate provided in the lubricant composition in an amount, in terms of molybdenum, of from 800 to 1300 ppm. In a particular embodiment, a molybdenum dialkyldithiocarbamate may be provided in an amount of from 0.1 to 5% by weight of the lubricant composition, and preferably in an amount of from 0.5 to 3% by weight of the lubricant compositions and more preferably, in certain compositions from 0.75 to 1.5% by weight of the lubricant composition.

[0021] The molybdenum dialkyldithiocarbamate may be provided in the lubricant composition in an amount, in terms of molybdenum, of from 100 to 5000 ppm, preferably from 500 to 3000 ppm and more preferably from 750 to 1500 ppm. In one embodiment, molybdenum dialkyldithiocarbamate provided in the lubricant composition in an amount, in terms of molybdenum, of from 800 to 1300 ppm. The organic friction modifier may be a metal-free organic friction modifier. Preferably the organic friction modifier is free from sulphur and/or phosphorus. Suitable organic friction modifiers may include, but are not limited to, imidazolines, amides, amines, succinimides, alkoxylated amines, alkoxylated ether amines, amine oxides, amidoamines, nitriles, imines, amino guanidines, alkanolamides, glycerol esters, and olefins, sunflower oil and other naturally occurring plant or animal oils, dicarboxylic acid esters, esters or partial esters of a polyol and one or more aliphatic or aromatic carboxylic acids, and the like. The organic friction modifier used in the compositions of the present invention may comprise one or a combination of organic friction modifiers defined herein.

[0022] Suitable organic friction modifiers may contain hydrocarbyl groups that are selected from straight chain, branched chain, or aromatic hydrocarbyl groups or mixtures thereof, and may be saturated or unsaturated. The hydrocarbyl groups may be composed of carbon and hydrogen or hetero atoms such as nitrogen or oxygen. The hydrocarbyl groups may range from about 12 to about 25 carbon atoms. In some embodiments the organic friction modifier may be a long chain fatty acid ester. In an embodiment the long chain fatty acid ester may be a mono-ester, or a di-ester, or a (tri)glyceride. The organic friction modifier may be a long chain fatty amide, a long chain fatty ester, a long chain fatty epoxide derivative, or a long chain imidazoline.

[0023] Other suitable organic friction modifiers may include organic, ashless (metal-free), nitrogen-free organic friction modifiers. Such organic friction modifiers may include esters formed by reacting carboxylic acids and anhydrides with alkanols and generally include a polar terminal group (e.g. carboxyl or hydroxyl) covalently bonded to an oleophilic hydrocarbon chain. An example of an organic ashless nitrogen-free friction modifier is known generally as glycerol monooleate (GMO) which may contain mono-, di-, and tri-esters of oleic acid. Other suitable friction modifiers are described in U.S. 6,723,685.

[0024] Suitable organic friction modifiers may be aminic organic friction modifiers which include amines or polyamines. Such compounds can have hydrocarbyl groups that are linear, either saturated or unsaturated, or a mixture thereof and may contain from about 12 to about 25 carbon atoms. Further examples of suitable organic friction modifiers include alkoxylated amines and alkoxylated ether amines. Such compounds may have hydrocarbyl groups that are linear, either saturated, unsaturated, or a mixture thereof. They may contain from about 12 to about 25 carbon atoms. Examples include ethoxylated amines and ethoxylated ether amines. The amines and amides may be used as such or in the form of an adduct or reaction product with a boron compound such as a boric oxide, boron halide, metaborate, boric acid or a mono-, di- or tri-alkyl borate. Other suitable organic friction modifiers are described in U.S. 6,300,291.

[0025] Preferably, the organic friction modifier may be present in amount of up to about 10% by weight of the lubricant composition, preferably up to about 5% by weight.

Preferably, the organic friction modifier is present in an amount of from about 0.1% by weight to about 4% by weight and more preferably up to about 1% by weight of the lubricant composition.

[0026] The organic friction modifier may comprise an organic ashless nitrogen-free friction modifier and preferably is glycerol monooleate (GMO). According to this embodiment, the lubricant composition and the additive composition comprise the molybdenum dialkyldithiocarbamate and GMO, preferably in the aforementioned amounts.

[0027] In another particular embodiment, the organic friction modifier may further comprise fatty acid amide having from about 12 to about 25 carbon atoms and preferably is oleylamide. According to this embodiment the lubricant composition and the additive composition comprise the molybdenum dialkyldithiocarbamate and oleylamide, preferably in the aforementioned amounts.

[0028] In accordance with the present invention, the organic friction modifier is and/or the lubricant composition and additive - composition comprises an oil-soluble mono-, di- or tri- glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof.

[0029] The lubricant composition of one aspect of the invention comprises a base oil composition of lubricating viscosity; and an additive composition comprising a molybdenum dialkyldithiocarbamate and an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof.

[0030] Disclosed herein is an additive composition for use in a lubricant composition defined above, comprising a molybdenum dialkyldithiocarbamate and an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof.

[0031] The oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof may be provided in an amount of up to 5% by weight of the lubricant composition, preferably from 0.1 to 2.5% by weight of the lubricant composition, more preferably 0.25to 1% by weight of the lubricant composition.

[0032] In one embodiment, the oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof is provided in a percent by weight ratio relative to the molybdenum dialkyldithiocarbamate in the range from 1:3 to 3: 1, more preferably 1 :3 to 1 :1, still more preferably in the range 1 :2 to 2:3.

[0033] The additive composition allows a lubricant composition to be produced that has excellent longevity and provides a high performance oil. The present composition allows this longevity and performance to be achieved with very little or reduced molybdenum dialkyldithiophosphate content or no molybdenum dialkyldithiophosphate. The composition comprises no more than 0.1% molybdenum dialkyldithiophosphate, still more preferably no more than 0.05 % molybdenum dialkyldithiophosphate and most preferably the additive composition is absent molybdenum dialkyldithiophosphate.

[0034] In a preferred embodiment, the lubricant composition and the additive composition further comprises, in addition to the oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof described above, a long chain fatty amide, and more preferably comprises oleylamide, which may optionally be in the amount of up to 1% by weight of the lubricant composition, preferably in the amount of up to 0.5% by weight of the lubricant composition and more preferably in the amount of from 0.05 to 0.25% by weight of the lubricant composition. Optionally, oleylamide may be provided in a weight percent ratio relative to the oil-soluble mono-, di- or tri- glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof in the range of from 1: 10 to 1:1, more preferably from 1:6 to 1:4 and most preferably about 1:5.

[0035] The lubricant composition and additive composition may further comprise further additive components, which may include other anti-wear additives (but preferably not an organometallic dithiophosphate anti-wear additive, especially not zinc or molybdenum based organometallic dithiophosphate anti-wear additives), dispersants, dispersant viscosity modifiers, detergents, corrosion inhibitors, anti-oxidants, anti-foaming agents, or other additives. Such further additive components further make up no more than 5% and more preferably no more than 3% by weight of the lubricant composition.

[0036] In one particular embodiment, there are no further dispersant additives used in the composition of the invention.

[0037] The additive composition may make up a proportion of the lubricant composition of up to 20% by weight, more preferably of up to 10% by weight and more preferably of between 2.5 and 7.5% by weight, e.g. from 3% to 6% by weight.

[0038] As used herein, an additive concentrate comprises an additive composition and an additive carrier which may typically be a polar base oil and preferably comprises part of a base oil composition. Typically an additive concentrate provides a stable concentrate that can be made up to a lubricant composition by addition of appropriate base oils.

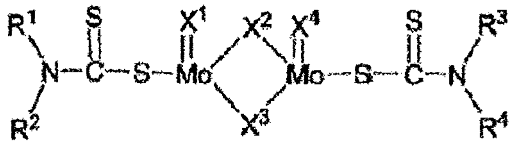
[0039] An additive composition, as used herein, comprises components other than a base oil composition.

[0040] A lubricant composition having an additive composition such as that defined above has improved properties useful in gear oils, especially for robot gear and gear having a rolling element, such as low wear, reduced sludge formation. These properties reduce the risk of catastrophic failure and allow that the lubricant composition meets the longevity requirements of these applications. An aspect of the invention is thus directed to the use of a lubricant composition as defined above for gear boxes having a rolling element, especially robot gearboxes or wind turbine gears.

[0041] Disclosed herein but not forming part of the present invention is an additive pack for later blending with a base oil composition or base stock to produce the lubricant composition locally. Optionally, the additive pack may be provided as a concentrate, which may comprise a portion of the base oil composition to be used, such as defined above, or one component base stock of the base oil, such as, for example, an alkylated naphthalene. An additive concentrate may, for example, comprise the additive composition in a weight percent ratio in the range 1:5 to 5:1, preferably from 1:2 to 3:1, more preferably from 1:1 to 1:2 for later dilution to the desired amount in a lubricant composition for use.

[0042] The molybdenum dialkyldithiocarbamate (MoDTC) may be any suitable MoDTC. For example, it can be a compound of Formula 1 below:

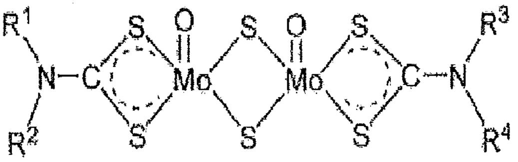
Formula 1:



where R^1 to R^4 denote alkyl groups and X^1 to X^4 each denote a sulphur atom or an oxygen atom.

[0043] Preferably, the MoDTC is a compound of Formula 2 below:

Formula 2



where R^1 to R^4 denote alkyl groups.

[0044] The alkyl groups R^1 to R^4 in the molybdenum dialkyldithiocarbamates of Formula 1 and Formula 2 are preferably each independently lipophilic groups of 1 to 30 carbons, and it is preferable that at least one or two of these four lipophilic groups is a secondary lipophilic group. Preferably, the alkyl groups R^1 to R^4 are C8 to C13 branched secondary lipophilic groups. The molybdenum dialkyldithiocarbamate may be provided in the lubricant composition in an amount, in terms of molybdenum, of from 100 to 5000 ppm, preferably from 500 to 3000 ppm and more preferably from 750 to 1500 ppm. In one embodiment, molybdenum dialkyldithiocarbamate provided in the lubricant composition in an amount, in terms of molybdenum, of from 800 to 1300 ppm.

[0045] A molybdenum dialkyldithiocarbamate used in accordance with the present invention may preferably have an elemental analysis value for molybdenum of from 9.5 to 10.5 mass %.

[0046] In one embodiment in which the molybdenum dialkyldithiocarbamate has an elemental analysis value for molybdenum of 10 mass %, the molybdenum dialkyldithiocarbamate may be provided in an amount of from 0.1 to 5% by weight of the lubricant composition, and preferably in an amount of from 0.5 to 3% by weight of the lubricant compositions and more preferably, in certain compositions from 0.75 to 1.5% by weight of the lubricant composition.

[0047] The content of molybdenum dialkyldithiocarbamate in a lubricating oil composition can be determined by carrying out an elemental analysis using an ICP (Inductively Coupled Plasma atomic emission spectroscopy, hereinafter referred to sometimes as ICP) analysis apparatus. The amount of molybdenum can also be measured by the ICP method.

[0048] Weight % amounts of molybdenum dialkyldithiocarbamates and weight ratios of other components to molybdenum dialkyldithiocarbamates as used herein are based upon molybdenum dialkyldithiocarbamate compounds (that is, compositions of molybdenum dialkyldithiocarbamate compounds) having a molybdenum content of 10 wt%. Thus, in using molybdenum dialkyldithiocarbamate compositions having a different wt% content of molybdenum, such values are adapted accordingly.

[0049] As mentioned above, combinations of organic friction modifiers may be used.

[0050] The organic friction modifier is or comprises an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof.

[0051] Any suitable oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof may be used.

[0052] Preferably, the hydroxy polycarboxylic acid has at least one hydroxy group or derivative (for example ether or ester) thereof, which is in an alpha position with respect to a carboxylic moiety.

Each hydroxy polycarboxylic acid may independently have from 4 to 22 carbon atoms, for example 4 to 15 carbon atoms. The oil-soluble mono-, di-, or triglyceride of at least one hydroxy polycarboxylic acid or derivative thereof may suitably have from 16 to 80 carbon atoms. The number of carbon atoms in the glyceride may affect its solubility in oil of lubricating viscosity and/or in liquid fuel.

[0053] By oil-soluble is meant that the glyceride is soluble in an oil of lubricating viscosity in a friction modifying and/or anti-wear amount, for example in an amount by weight of at least 200 ppm in an oil of lubricating viscosity. The solubility may be determined at ambient temperature, for example at 20° C. Preferably, the oil-soluble glyceride is soluble at 0° C. The solubility may be determined at atmospheric pressure.

[0054] Suitable hydroxy polycarboxylic acids include: citric acid (also sometimes called 3- carboxy-3 -hydroxy pentanedioic acid; 2-hydroxypropane- 1,2, 3 -tricarboxylic acid; or 3-hydroxypentanedioic acid-3 -carboxylic acid); tartaric acid (also sometimes called 2,3-dihydroxybutanedioic acid; or 2,3-dihydroxysuccinic acid); malic acid (also sometimes called hydroxybutanedioic acid); monohydroxy trimesic acid; and hydrogenated monohydroxy trimesic acid (sometimes also called 1,3,5-tricarboxy, 2-hydroxy cyclohexane).

[0055] The oil-soluble mono-, di-, or tri-glyceride of at least one hydroxy polycarboxylic acid, or an ether or an ester derivative thereof may be a di-, or tri-glyceride which is a glyceride of at least one hydroxy polycarboxylic acid and at least one second carboxylic acid which is a saturated, mono-unsaturated or poly-unsaturated, branched or linear, monocarboxylic or polycarboxylic acid having 4 to 22 carbon atoms, or a derivative thereof.

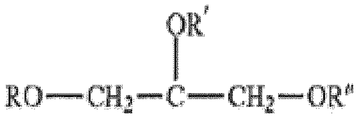
[0056] The second carboxylic acid may be saturated, mono-unsaturated or poly-unsaturated. Suitably, the second carboxylic acid is unsaturated. The second carboxylic acid may be branched or linear. The second carboxylic acid may be monocarboxylic or polycarboxylic acid. If the second carboxylic acid is a polycarboxylic acid, the derivative of the glyceride may be an ester of the second carboxylic acid group.

[0057] Suitable saturated second carboxylic acids include caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid and arachidic acid. Suitable unsaturated second carboxylic acids include oleic acid, linoleic acid, linolenic acid, myristoleic acid, palmitoleic acid, sapienic acid, eracic acid (also known as cis-13- docosenoic acid) and brassidic acid.

[0058] Preferably, the glyceride is a glyceride of citric acid and oleic acid, a glyceride of citric acid and linoleic acid or a mixture thereof.

[0059] The mono-, di-, or tri-glyceride of at least one hydroxy polycarboxylic acid or derivative thereof may be represented by the Formula 3:

Formula 3



$$RO-CH_2-\overset{\displaystyle OR'}{\overset{|}{C}}-CH_2-OR''$$

wherein RO, OR' and OR" independently represent:- OH; a saturated, mono-unsaturated or poly-unsaturated, branched or linear, monocarboxylic or polycarboxylic group having from 4 to 22 carbon atoms or an ether or an ester thereof; a hydroxy polycarboxylic acid moiety or an ether and/or ester thereof provided that at least one of RO, OR' and OR" is a hydroxy polycarboxylic acid moiety or an ether and/or ester thereof.

[0060] Preferably, in Formula 3, at least one of RO, OR' and OR" is a hydroxy polycarboxylic acid moiety or an ether and/or ester thereof and at least one of RO, OR' and OR" is a saturated, mono-unsaturated or poly-unsaturated, branched or linear, monocarboxylic or polycarboxylic group having from 4 to 22 carbon atoms or an ester thereof.

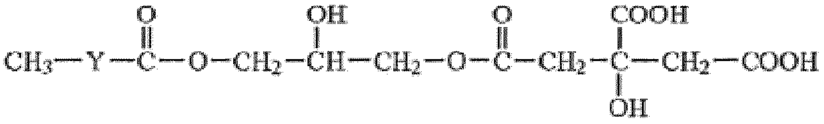
[0061] Preferably in Formula 3, the hydroxy polycarboxylic moiety acid has at least one hydroxy group or derivative (for example ether or ester) thereof which is in an alpha position with respect to a carboxylic moiety.

[0062] In Formula 3, each hydroxy polycarboxylic moiety may independently have from 4 to 22 carbon atoms. In formula 3, the hydroxy polycarboxylic moiety may be derivable from acids including for example citric acid, tartaric acid, malic acid, monohydroxy trimesic acid and hydrogenated monohydroxy trimesic acid.

[0063] In Formula 3, when present, each saturated, branched or linear, monocarboxylic or polycarboxylic group having from 4 to 22 carbon atoms or an ester thereof may be derivable from saturated carboxylic acids or their halide equivalents. Suitable saturated carboxylic acids include for example, caproic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid and arachidic acid. In Formula 3, when present, each mono-unsaturated or poly-unsaturated, branched or linear, monocarboxylic or polycarboxylic group having from 4 to 22 carbon atoms or an ester thereof may be derivable from unsaturated carboxylic acids or their halide equivalents. Suitable mono-unsaturated acids include for example, oleic acid, myristoleic acid, palmitoleic acid, sapienic acid, erucic acid and brassidic acid. Suitable polyunsaturated acids include for example linoleic acid and linolenic acid.

[0064] The glyceride may be a glyceride of at least one hydroxy polycarboxylic acid and a saturated C4 to C22 polycarboxylic acid, or an ether or an ester derivative thereof. The polycarboxylic acid may be branched or linear. The glyceride may be a glyceride of at least one hydroxy polycarboxylic acid and a mono-unsaturated or polyunsaturated C4 to C22 polycarboxylic acid, or an ether or an ester derivative thereof. The polycarboxylic acid may be branched or linear. The glyceride may be a glyceride of at least one hydroxy polycarboxylic acid and a saturated C4 to C22 monocarboxylic acid, or an ether or an ester derivative thereof. The monocarboxylic acid may be branched or linear. Suitable saturated C16 monocarboxylic acids include palmitic acid. Suitable saturated C18 monocarboxylic acids include stearic acid. The glyceride may be a glyceride of at least one hydroxy polycarboxylic acid and a mono-unsaturated or polyunsaturated C4 to C22 monocarboxylic acid, or an ether or an ester derivative thereof. The unsaturated monocarboxylic acid may be branched or linear. The glyceride may be a glyceride of at least one hydroxy polycarboxylic acid and an unsaturated C18 monocarboxylic acid, or an ether or an ester derivative thereof. The monocarboxylic acid may be branched or linear. Suitable hydroxy polycarboxylic acids include citric acid. The glyceride additive may be a glyceride of citric acid and an unsaturated C18 monocarboxylic acid, or an ether or an ester derivative thereof. Suitable unsaturated C18 monocarboxylic acids include oleic acid and linoleic acid.

[0065] The glyceride may be a citric acid ester of a mono-glyceride of a saturated, mono- unsaturated or polyunsaturated, branched or linear, monocarboxylic or polycarboxylic C4 to C22 carboxylic acid, suitably a C16 or C18 carboxylic acid for example, palmitic acid, stearic acid, oleic acid or linoleic acid. The glyceride may be a citric acid ester of monoglyceride made from vegetable oil, for example sunflower and/or palm oil. The glyceride may be a citric acid ester of mono-glyceride made from edible, refined sunflower and palm based oil. Preferably, the glyceride is a glyceride of citric acid and oleic acid, a glyceride of citric acid and linoleic acid or a mixture thereof. A suitable source of glycerides of citric acid with oleic acid and/or linoleic acid is GRINSTED CITREM SP70 (Trade Mark) which is available from Danisco DuPont. GRINSTED CITREM SP70 is believed to be a citric acid ester of mono-glyceride made from edible, refined sunflower and palm based oil. GRINSTED CITREM SP70 is also believed to comprise at least one diglyceride having the Formula 4:



$$CH_3-Y-\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_2-\overset{\overset{\displaystyle OH}{|}}{CH}-CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2-\underset{\underset{\displaystyle OH}{|}}{\overset{\overset{\displaystyle COOH}{|}}{C}}-CH_2-COOH$$

Formula 4

wherein- Y- represents a C16 hydrocarbyl moiety which is mono- or di-unsaturated.

[0066] Thus, diglycerides having Formula 4 include a glyceride of citric acid and oleic acid and a glyceride of citric acid and linoleic acid. This corresponds to a structure of Formula 3 in which (i) RO represents a carboxyl group having 18 carbon atoms, which may be derivable from oleic acid and/or linoleic acid, (ii) OR' represents a hydroxyl moiety, and (iii) OR" represents a hydroxy polycarboxylic acid moiety, which may be derivable from citric acid.

[0067] The glyceride may be an ester of citric acid with a partial glyceride, for example mono- or di-glyceride or mixtures thereof, which have free hydroxyl groups. Suitable partial glycerides include those derived from fatty acids with 12 to 18 carbon atoms, including for example those derived from coconut oil fatty acids and palm oil fatty acids. Examples include Lamegin® ZE 306, Lamegin® ZE 609 and Lamegin® ZE 618 (Cognis Deutschland GmbH & Co. KG). Thus the glyceride may be a citric acid ester of the monoglyceride of hydrogenated tallow fatty acid, for example Lamegin® ZE 309, or an ester of diacetyl tartaric acid with monoglyceride of hydrogenated tallow fatty acid, for example Lamegin® DW 8000, or citric acid ester based on sunflower oil fatty acid monoglyceride, for example Lamegin® ZE 609 FL. Such esters are described for example in US 5,770,185 and US 2010/0087319.

[0068] The derivative of the glyceride may be an ester of the at least one hydroxy polycarboxylic acid moiety. The ester may be an ester of a carboxylic acid moiety of the hydroxy polycarboxylic acid. Each carboxylic acid moiety of the hydroxyl polycarboxylic acid may be independently derivatisable as an ester. The ester derivative may be a hydrocarbyl ester, in which the hydrocarbyl moiety may have from 4 to 22 carbon atoms. The hydrocarbyl moiety may be an alkyl moiety which may have from 4 to 22 carbon atoms. The hydrocarbyl moiety may comprise one or more hetero atoms for example nitrogen and/or oxygen.

[0069] The derivative of the glyceride may be an ether or an ester of the hydroxyl moiety of the hydroxy polycarboxylic acid. If more than one hydroxy moiety is present in the mono-, di-, or tri-glyceride of at least one hydroxy polycarboxylic acid, each hydroxyl moiety may independently be derivatisable as an ether or an ester. Each ether may be a hydrocarbyl ether. The hydrocarbyl moiety of each ether may independently have from 1 to 22 carbon atoms, more suitably from 1 to 18 carbon atoms. The hydrocarbyl moiety of each ether may independently be an alkyl moiety. The alkyl moiety of each ether may independently have from 1 to 22 carbon atoms, more suitably from 1 to 18 carbon atoms. The hydrocarbyl moiety of each ether may independently comprise one or more hetero atoms for example nitrogen and/or oxygen. Each ester may independently be a hydrocarbyl ester. The hydrocarbyl moiety of each ester may have from 4 to 22 carbon atoms. The hydrocarbyl moiety of each ester may independently be an alkyl moiety. The alkyl moiety of each ester may independently have from 4 to 22 carbon atoms. The hydrocarbyl moiety of each ester may independently comprise one or more hetero atoms for example nitrogen and/or oxygen.

[0070] If the saturated, mono-unsaturated or polyunsaturated, branched or linear carboxylic acid having 4 to 22 carbon atoms is a polycarboxylic acid, the derivative of the glyceride may be an ester of a carboxylic acid moiety of one or more of the at least one saturated, mono-unsaturated or poly-unsaturated, branched or linear, polycarboxylic acid having from 4 to 22 carbon atoms, if present. Each ester may independently be a hydrocarbyl ester. The hydrocarbyl moiety of each ester may independently have from 4 to 22 carbon atoms. The hydrocarbyl moiety may be an alkyl moiety. The alkyl moiety of each ester may independently have from 4 to 22 carbon atoms. The hydrocarbyl moiety of each ester may independently comprise one or more hetero atoms for example nitrogen and/or oxygen.

[0071] The oil-soluble mono-, di-, or tri-glycerides of at least one hydroxy polycarboxylic acid and derivatives thereof may be made by methods known in the art. The di- and tri-glycerides may be made by partial hydrolysis of a fat to produce a mono-glyceride followed by esterification with a hydroxy polycarboxylic acid. The mono-glycerides may be made by esterification of glycerol with a hydroxy polycarboxylic acid. Hydrocarbyl ether derivatives may be made from corresponding hydrocarbyl halides.

[0072] As mentioned above, the lubricant composition and additive composition may further comprise further additive components.

[0073] Examples of further additive components include dispersants (metallic and non-metallic), dispersant viscosity modifiers, detergents (metallic and non-metallic), viscosity index improvers, viscosity modifiers, pour point depressants, rust inhibitors, corrosion inhibitors, anti-oxidants, anti-foaming agents, seal swell agents, extreme pressure and/or anti-wear additives (including non-metallic, phosphorus containing, non-phosphorus containing, sulphur containing, non-sulphur containing extreme pressure additives and phosphorus- and sulphur-containing hydrocarbons), surfactants, demulsifiers, anti-seizure agents, wax modifiers, lubricity agents, anti-staining agents, chromophoric agents and metal deactivators.

[0074] Dispersants (also called dispersant additives) help hold solid and liquid contaminants for example resulting from oxidation of the lubricant composition during use, in suspension and thus reduce sludge flocculation, precipitation and/or deposition for example on lubricated surfaces. They generally comprise long-chain hydrocarbons, to promote oil-solubility, and a polar head capable of associating with material to be dispersed. Examples of suitable dispersants include oil soluble polymeric hydrocarbyl backbones each having one or more functional groups which are capable of associating with particles to be dispersed. The functional groups may be amine, alcohol, amine-alcohol, amide or ester groups. The functional groups may be attached to the hydrocarbyl backbone through bridging groups. More than one dispersant may be present in the additive concentrate and/or lubricant composition. Optionally the composition is absent such dispersants.

[0075] Examples of suitable ashless dispersants include oil soluble salts, esters, amino-esters, amides, imides and oxazolines of long chain hydrocarbon-substituted mono- and polycarboxylic acids or anhydrides thereof; thiocarboxylate derivatives of long chain hydrocarbons; long chain aliphatic hydrocarbons having polyamine moieties attached directly thereto; Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and polyalkylene polyamine; Koch reaction products and the like. Examples of suitable dispersants include derivatives of long chain hydrocarbyl-substituted carboxylic acids, for example in which the hydrocarbyl group has a number average molecular weight of up to 20000, for example 300 to 20000, 500 to 10000, 700 to 5000 or less than 15000. Examples of suitable dispersants include hydrocarbyl-substituted succinic acid compounds, for example succinimide, succinate esters or succinate ester amides and in particular, polyisobutenyl succinimide dispersants. The dispersants may be borated or non-borated.

[0076] Additionally or alternatively, dispersancy may be provided by polymeric compounds capable of providing viscosity index improving properties and dispersancy. Such compounds are generally known as dispersant viscosity improver additives or multifunctional viscosity improvers. Examples of suitable dispersant viscosity modifiers may be prepared by chemically attaching functional moieties (for example amines, alcohols and amides) to polymers which tend to have number average molecular weights of at least 15000, for example in the range 20000 to 600000 (for example as determined by gel permeation chromatography or light scattering methods). Examples of suitable dispersant viscosity modifiers and methods of making them are described in WO 99/21902, WO2003/099890 and WO2006/099250. More than one dispersant viscosity modifier may be present in the additive concentrate and/or lubricant composition.

[0077] Detergents (also called detergent additives) may help reduce high temperature deposit formation for example on metallic surfaces within machinery, including for example high-temperature varnish and lacquer deposits, by helping to keep finely divided solids in suspension in the lubricant composition. Detergents may also have acid-neutralising properties. Ashless (that is non-metal containing) detergents may be present. Metal-containing detergent comprises at least one metal salt of at least one organic acid, which is called soap or surfactant. Detergents may be overbased in which the detergent comprises an excess of metal in relation to the stoichiometric amount required to neutralise the organic acid. The excess metal is usually in the form of a colloidal dispersion of metal carbonate and/or hydroxide. Examples of suitable metals include Group I and Group 2 metals, more suitably calcium, magnesium and combinations thereof, especially calcium. More than one metal may be present.

[0078] Examples of suitable organic acids include sulphonic acids, phenols (sulphurised or preferably sulphurised and including for example, phenols with more than one hydroxyl group, phenols with fused aromatic rings, phenols which have been modified for example alkylene bridged phenols, and Mannich base-condensed phenols and saligenin-type phenols, produced for example by reaction of phenol and an aldehyde under basic conditions) and sulphurised derivatives thereof, and carboxylic acids including for example, aromatic carboxylic acids (for example hydrocarbyl-substituted salicylic acids and sulphurised derivatives thereof, for example hydrocarbyl substituted salicylic acid and derivatives thereof). More than one type of organic acid may be present.

[0079] Additionally or alternatively, non-metallic detergents may be present. Suitable non-metallic detergents are described for example in U.S. Pat. No. 7,622,431.

[0080] More than one detergent may be present in the lubricant composition and/or additive concentrate.

[0081] Viscosity Index Improvers/Viscosity Modifiers Viscosity index improvers (also called viscosity modifiers, viscosity improvers or VI improvers) impart high and low temperature operability to a lubricant composition and facilitate it remaining shear stable at elevated temperatures whilst also exhibiting acceptable viscosity and fluidity at low temperatures.

[0082] Examples of suitable viscosity modifiers include high molecular weight hydrocarbon polymers (for example polyisobutylene, copolymers of ethylene and propylene and higher alpha-olefins); polyesters (for example polymethacrylates); hydrogenated poly(styrene-co-butadiene or isoprene) polymers and modifications (for example star polymers); and esterified poly(styrene-co-maleic anhydride) polymers. Oil-soluble viscosity modifying polymers generally have number average molecular weights of at least 15000 to 1000000, preferably 20000 to 600000 as determined by gel permeation chromatography or light scattering methods.

[0083] Viscosity modifiers may have additional functions as multifunction viscosity modifiers. More than one viscosity index improver may be present.

[0084] Pour point depressants (also called lube oil improvers or lube oil flow improvers), lower the minimum temperature at which the lubricant will flow and can be poured. Examples of suitable pour point depressants include C8 to C18 dialkyl fumarate/vinyl acetate copolymers, methacrylates, polyacrylates, polyarylamides, polymethacrylates, polyalkyl methacrylates, vinyl fumarates, styrene esters, condensation products of haloparaffm waxes and aromatic compounds, vinyl carboxylate polymers, terpolymers of dialkyfumarates, vinyl esters of fatty acids and allyl vinyl ethers, wax naphthalene and the like.

[0085] More than one pour point depressant may be present.

[0086] Rust inhibitors generally protect lubricated metal surfaces against chemical attack by water or other contaminants. Examples of suitable rust inhibitors include non-ionic polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, polyoxyalkylene polyols, anionic alky sulphonic acids, metal phenolates, basic metal sulphonates, fatty acids and amines. Preferably the rust inhibitor is not a zinc dithiophosphate.

[0087] More than one rust inhibitor may be present.

[0088] Corrosion inhibitors (also called anti-corrosive agents) reduce the degradation of metallic parts contacted with the lubricant composition. Examples of corrosion inhibitors include phosphosulphurised hydrocarbons and the products obtained by the reaction of phosphosulphurised hydrocarbon with an alkaline earth metal oxide or hydroxide, non-ionic polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, thiadiazoles, triazoles and anionic alkyl sulphonic acids. Examples of suitable epoxidised ester corrosion inhibitors are described in US2006/0090393.

[0089] More than one corrosion inhibitor may be present.

[0090] Antioxidants (sometimes also called oxidation inhibitors) reduce the tendency of oils to deteriorate in use. Evidence of such deterioration might include for example the production of varnish-like deposits on metal surfaces, the formation of sludge and viscosity increase. Examples of suitable antioxidants include alkylated diphenylamines, N-alkylated phenylenediamines, phenyl-α-naphthylamine, alkylated phenyl-α-naphthylamines, dimethylquinolines, trimethyldihydroquinolines and oligomeric compositions derived therefrom, hindered phenolics (including ashless (metal-free) phenolic compounds and neutral and basic metal salts of certain phenolic compounds), aromatic amines (including alkylated and non-alkylated aromatic amines), sulphurised alkyl phenols and alkali and alkaline earth metal salts thereof, alkylated hydroquinones, hydroxylated thiodiphenyl ethers, alkylidenebisphenols, thiopropionates, metallic dithiocarbamates, 1,3,4-dimercaptothiadiazole and derivatives, oil soluble copper compounds (for example, copper dihydrocarbyl thio- or thio-phosphate, copper salts of a synthetic or natural carboxylic acids, for example a C8 to C18 fatty acid, an unsaturated acid or a branched carboxylic acid, for example basic, neutral or acidic Cu(I) and/or Cu(II) salts derived from alkenyl succinic acids or anhydrides), alkaline earth metal salts of alkylphenolthioesters, suitably having C5 to C12 alkyl side chains, calcium nonylphenol sulphide, barium t-octylphenyl sulphide, dioctylphenylamine, phosphosulphised or sulphurised hydrocarbons, oil soluble phenates, oil soluble sulphurised phenates, calcium dodecylphenol sulphide, phosphosulphurised hydrocarbons, sulphurised hydrocarbons, phosphorus esters, low sulphur peroxide decomposers and the like.

[0091] More than one anti-oxidant may be present. More than one type of anti-oxidant may be present.

[0092] Anti-foams (sometimes also called anti-foaming agents) retard the formation of stable foams. Examples of suitable anti-foam agents include silicones, organic polymers, siloxanes (including poly siloxanes and (poly) dimethyl siloxanes, phenyl methyl siloxanes), acrylates and the like.

[0093] More than one anti-foam may be present.

[0094] Seal swell agents (sometimes also called seal compatibility agents or elastomer compatibility aids) help to swell elastomeric seals for example by causing a reaction in the fluid or a physical change in the elastomer. Examples of suitable seal swell agents include long chain organic acids, organic phosphates, aromatic esters, aromatic hydrocarbons, esters (for example butylbenzyl phthalate) and polybutenyl succinic anhydride.

[0095] More than one seal swell agent may be present.

[0096] Examples of other additives which may be present in the lubricant composition and/or additive concentrate include extreme pressure and/or anti-wear additives (including non-metallic, phosphorus containing, non-phosphorus containing, sulphur containing, non-sulphur containing extreme pressure additives and phosphorus- and sulphur-containing hydrocarbons), surfactants, demulsifiers, anti-seizure agents, wax modifiers, lubricity agents, anti-staining agents, chromophoric agents and metal deactivators.

[0097] The base oil composition used in the present aspect preferably makes up at least 75% by weight of the lubricant composition, more preferably at least 80%, still more preferably at least 85%, still more preferably at least 90%. More preferably still, the base oil composition makes up from 92 to 97% by weight, such as at least 94%.

[0098] The base oil composition may be any suitable base oil and may selected from mineral oils, synthetic oils, vegetable and animal oils and mixtures thereof used in conventional lubricating oils as appropriate. Specific examples thereof include base oils of groups I, II, III, IV or V in the API (American Petroleum Institute) standard in base oil categories according to API standard 1509, "ENGINE OIL LICENSING AND CERTIFICATION SYSTEM", April 2007 version, 16th edition Appendix E, as set out in Table 1.

Table 1

Group	Saturated hydrocarbon content (% by weight) ASTM D2007		Sulphur content (% by weight) ASTM D2622 or D4294 or D4927 or 03120		Viscosity Index ASTM D2270
I	<90	and/or	>0.03	and	≧80 and <120
II	≧90	and	≦0.03	and	≧80 and <120
III	≧90	and	≦0.03	and	≧120
IV	polyalpha olefins				
V	all base stocks not in Groups I, II, III or IV				

[0099] Group I, Group II and Group III base stocks may be derived from mineral oils. Group I base stocks are typically manufactured by known processes comprising solvent extraction and solvent dewaxing, or solvent extraction and catalytic dewaxing. Group II and Group III base stocks are typically manufactured by known processes comprising catalytic hydrogenation and/or catalytic hydrocracking, and catalytic hydroisomerisation. A suitable Group I base stock is AP/E core 150, available from ExxonMobil. Suitable Group II base stocks are EHC 50 and EHC 110, available from ExxonMobil. Suitable group III base stocks include Yubase 4 and Yubase 6 available for example, from SK Lubricants. Suitable Group V base stocks are ester base stocks, for example Priolube 3970, available from Croda International plc. Suitable Group IV base stocks include hydrogenated oligomers of alpha olefins. Suitably, the oligomers may be made by free radical processes, Zeigler catalysis or by cationic Friedel-Crafts catalysis. Poly-alpha-olefin base stocks may be derived from C8, C10, C12, C14 olefins and mixtures of one or more thereof. In one embodiment, the poly-alpha-olefin base stock may be derived from C10 and C12 olefins.

[0100] The lubricant composition and the oil of lubricating viscosity may comprise one or more base oil and/or base stock which is/are natural oil, mineral oil (sometimes called petroleum-derived oil or petroleum-derived mineral oil), non-mineral oil and mixtures thereof. Natural oils include animal oils, fish oils, and vegetable oils. Mineral oils include paraffinic oils, naphthenic oils and paraffinic-naphthenic oils. Mineral oils may also include oils derived from coal or shale.

[0101] Suitable base oils and base stocks may be derived from processes such as chemical combination of simpler or smaller molecules into larger or more complex molecules (for example polymerisation, oligomerisation, condensation, alkylation, acylation).

[0102] Suitable base stocks and base oils may be derived from gas-to-liquids materials, coal-to-liquids materials, biomass-to-liquids materials and combinations thereof.

[0103] Preferably, the base oil is a synthetic base oil comprising a poly-alpha-olefin component.

[0104] There is provided, in a preferred embodiment for use in the lubricant composition of the first aspect of the present invention, a base oil comprising a modified poly-alpha-olefin. Any suitable amount of the modified poly-alpha-olefin may be used and it may comprise 5 to 95% by weight of the total composition, more preferably 10 to 90% by weight and optionally from 30 to 88% by weight. Preferably, the base oil according to this embodiment is a synthetic base oil and more preferably comprises a conventional poly-alpha-olefin. Optionally, the base oil further comprises one or more additive carriers, which may be typically selected from other base stocks such as Group V base stocks, optionally polymeric or non-polymeric base stocks and optionally having a polar component. Preferably the additive carrier is not elastomer shrinking and more preferably is elastomer swelling.

[0105] A modified poly-alpha-olefin may preferably be a functionalised poly-alpha olefin, preferably functionalised with a relatively polar functional group, such as an ester group. Preferably, the olefin to ester ratio in the modified poly-alpha-olefin is in the range from 20:1 to 1:1. A modified poly-alpha-olefin, as used herein, is preferably obtainable and preferably obtained by co-polymerisation of one or more alpha-olefin monomers with a monomer having a relatively polar functional group, e.g. an olefinic monomer having or adapted to have a relatively polar functional group. The modified poly-alpha-olefin preferably comprises a co-polymer of one or more alpha-olefin monomers with ester (e.g. an alkyl ester of an acid, such as an alkyl ester of a dicarboxylic acid) and preferably an olefinic alkyl ester. Other ester functional groups may include butanedioic and succinic anhydride. One example of the modified poly-alpha-olefin is a co-polymer of an alpha-olefin monomer (e.g. with a dodecene chain length) with an olefinic alkyl esters, for example with an olefinic alkyl ester having a decene olefin chain length and in a ratio of alpha olefin monomer and functionalised monomer in the range 3:2 to 5:1, preferably 2:1 to 3:1 and preferably in a randomised copolymer. Examples of commercially available modified poly-alpha-olefins include but are not limited to Aria™ WTP 40 or a Ketjenlube™ grade such as Ketjenlube™ 240.

[0106] Preferably, the modified poly-alpha-olefin is selected from a kinematic viscosity at 100°C of 40 cSt or 100 cSt or thereabout. For use in robot gears, it is preferred that the modified poly-alpha-olefin has a kinematic viscosity at 100°C of 40 cSt or thereabout. For use in wind turbines or industrial gear, it is preferred that the modified poly-alpha-olefin has a kinematic viscosity at 100°C of 100 cSt or thereabout.

[0107] Any suitable poly-alpha-olefin may be used, but preferably a relatively low viscosity poly-alpha-olefin (by which it is meant low viscosity relative to the modified poly-alpha-olefin), such as a PAO 8. Optionally, the poly-alpha-olefin may be or may include or comprise a high viscosity poly-alpha-olefin, such as a high viscosity conventional poly-alpha-olefin (e.g. conventional PAO 40 and/or 100) and/or a metallocene poly-alpha-olefin (e.g. metallocene PAO 50 and/or 135).

[0108] Particular base stocks may be selected and particular base oils may be formulated to provide any suitable viscosity grade of base oil, as required. The lubricant composition may have any suitable viscosity grade (defined by kinematic viscosity at 40°C), such as from 60 to 700 cSt, more preferably 68 to 680 cSt.

[0109] In one preferred embodiment, the base oil may comprise the modified poly-alpha-olefin and poly-alpha-olefin in a weight ratio of 25:75 to 85:15, more preferably from 40:60 to 80:20, optionally 50:50 or a greater proportion of the modified poly-alpha-olefin, such as in the range 60:40 to 75:25. A ratio of about 70:30 may be provided in one embodiment. Preferably, according to this embodiment, the modified poly-alpha olefin has a kinematic viscosity at 100°C of 40 cSt or thereabout and is suitable for use in formulating a lubricating composition with a viscosity grade defined by a kinematic viscosity of 150 cSt at 40°C and is preferably for use in robotic gears. The modified poly-alpha-olefin and poly-alpha-olefin may make up the major part of the base oil composition and preferably at least 60% by weight of the base oil composition, more preferably at least 75% by weight of the base oil composition. More preferably, it makes up at least 85% of the base oil composition and optionally at least 90%.

[0110] A preferred base oil composition comprises one or more additive carriers. The additive carriers preferably serve to increase the polarity of the base oil and may preferably be used as the base stock component of an additive concentrate. Such additive carrier may be a Group V base stock. Preferably the additive carrier is a relatively polar base stock. Optionally, an additive carrier may have a kinematic viscosity at 40°C of from 20 to 40 cSt, preferably 25-35 cSt. The additive carrier may be, for example, selected from alkylated naphthalene, alkyl benzene or low viscosity esters, preferably, alkylated naphthalene or low viscosity alkylbenzene is used. A low viscosity ester may be for example a diisodecyl adipate (DIDA) or a diiso tridecyl adipate (DITA), which may be present in the base oil in an amount of up to 20% by weight, but more preferably up to 15% by weight and still more preferably up to 10% by weight and in any case at least 5% by weight. Preferably, the additive carrier comprises (and still more preferably is) an alkylated naphthalene and is provided in an amount of up to 25% by weight of the base oil composition, preferably up to 15%. The alkylated naphthalene is preferably provided in an amount of at least 5%, preferably at least 7.5% and preferably in an amount up to 12%, more preferably 10% of the base oil composition.

[0111] Base oil compositions of the present embodiment are particular advantageous in lubricant compositions of the present invention in that they provide a stable lubricant composition that can provide longevity, are less liable to sludge, and are capable of effectively solubilising an additive composition such as that defined above. The base oil composition of the present embodiment also provides excellent elastomer compatibility properties.

[0112] The base oil according to a preferred embodiment may enable for the lubricant composition a viscosity of from 130 to 170 cSt at 40°C, more preferably 135 to 165 cSt at 40°C.

[0113] In a preferred embodiment of the invention, a lubricant composition is provided as a synthetic gear oil composition suitable for use as a lubricant for gearboxes comprising a rolling element, comprising a base oil composition comprising a modified poly-alpha- olefin such as that defined above; and an additive composition comprising a molybdenum di-alkyldithiocarbamate and an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof, which has no more than 0.1% by weight of molybdenum dithiophosphate.

EXAMPLES

[0114] Lubricant compositions were prepared for comparison with commercially available lubricant oils and subject to a number of performance tests to compare the performance as gear oils, particularly as robot gear oils. In particular, tests were provided for wear, including a gear wear test, a bearing gear performance test and elastomer compatibility tests.

[0115] The performance or wear tests carried out are summarised below.

[0116] FZG test: this test is a well-known test designed to test wear performance of a lubricating oil at the interface of a set of gears. For this test, gears are loaded through a torsional coupling that is set to known load conditions or stages. The gears are rotated by a variable speed electric motor. Fluid temperature is controlled by heating and/or cooling elements. The test evaluates gear tooth face scuffing resistance of fluids using A profile gears. A rig is operated at 1450 rpm through up to 12 progressive load stages at 15 minute intervals. Standard tests are run at a fluid temperature of 90°C. Gear teeth are inspected after each load stage for scuffing. The test was carried out according to the test method defined in ISO14635-1. Load carrying capacity before failure was identified by failure stage and determined as pass/fail. A fail was considered failure to reach failure stage 12 or greater under the test conditions. The evaluation of failure condition is when cumulative scratch width on the gear exceeds 20 mm. This is indicative of scuffing wear.

[0117] FE8 test: the FE8 test is recognised within the industry and a good means of evaluating bearing gear performance. Both rolling and sliding lubrication conditions are present in the same test and so the test is particularly suited at testing performance of a lubricant for use in gears having rolling elements. Two steps of the FE8 test were carried out. In step 1, wear and torque performance are measured and can be used to evaluate performance of a lubricant composition. In step 2, long term integrity of the product is examined. Test pieces, including rollers and washers, were visually examined to assess for surface finish.

[0118] The FE8 tests were carried out consistent with DIN-51819-3. Test duration and loss of weight of bearing components are used to classify the aptitude of the lubricant. The test bearings used are cylindrical roller thrust bearings 81212 with brass cage. One bearing consists of 15 cylindrical rolling elements, a brass cage, a housing washer and a shaft washer. The material of the washers and rolling elements is usual bearing steel 100Cr6 and the material of the cage is CuZn40. The bearings are manufactured by FAG, Schweinfurt. An advantage of using a cylindrical bearing in an anti-wear test is that there is a high amount of slippage (maximum 14.8%) and so anti-wear requirements on lubricant is high.

[0119] In the FE8 test, the test bench is equipped with two cylindrical roller thrust bearings. The test bearings are strained with a disc spring package to provide the axial test force. A heat shield heats the test head by convection heating and a radial fan is used to reduce temperature if required.

[0120] For FE8 step 1, a load of 80 kN is applied with a 7.5 rpm speed at 80°C, over 80 hours. A 4 litre oil reservoir is used with a 0.1 litre/minute flow rate per bearing. Wear of bearings is measured in terms of weight loss of roller sets, rings and cage. Less than 30 mg wear of the roller sets is considered acceptable under the DIN-51819-3 methodology.

[0121] For FE8 step 2, a load of 80 kN is applied with 75 rpm speed at 70°C, over 800 hours. Again a 4 litre oil reservoir is used with a 0.1 litre/minute flow rate per bearing.

[0122] As elastomer compatibility testing, condition of both elastomers and the oil after the elastomer compatibility tests was assessed, to be able to provide an assessment of sludge formation as an elastomer compatibility component. Two static elastomer compatibility tests were carried out: elastomer material 72NBR902 was tested at 95°C over 1008 hours (referred to as the NBR test) and an elastomer material 75FKM585 was tested at 120°C over 1008 hours (referred to as the FKM test). In each case change in mass, volume, shore A hardness, tensile strength and rupture elongation were measured in percentage terms relative to a reference. The NBR and FKM tests were carried out in line with ISO 1817. The used oil from the NBR and FKM tests was visually assessed for colour change relative to a fresh oil and sludge formation to further characterise elastomer compatibility.

Example 1

[0123] Sample lubricant oil formulations were prepared by providing a base oil comprising a mixture of base stocks and blending therewith an additive composition comprising at least an anti-wear agent and other additives in a diluent (the diluent being one of the base stocks). The formulations are summarised in Table 2 below:

Table 2: sample lubricant compositions (wt % content)

Sample No:		S1	S2	S3	| S4	S5	| S6
Base oil							
PAO 8		25	25	28	28	28	28

(continued)

Sample No:		S1	S2	S3	S4	S5	S6
Base oil							
Modified PAO (commercially available as Aria WTP 40)		60	60	60	60	60	60
Alkylated naphthalene		11.132	10.532	7.897	7.997	8.397	8.497
Sub-total		96.132	95.532	95.897	95.997	96.397	96.497
Additive composition							
MoDTC		1.25	1.25	0.9	0.9	0.9	0.9
Phenolic antioxidant		0.095	0.095	0.095	0.095	0.095	0.095
Aminic antioxidant		0.095	0.095	0.095	0.095	0.095	0.095
Yellow metal passivator		0.008	0.008	0.008	0.008	0.008	0.008
Metal-containing detergent, e.g. Calcium		1.695	1.695	1.68	1.68	1.68	1.68
S+P EP/AW booster, aliphatic, C3-C8		0.095	0.095	0.095	0.095	0.095	0.095
S+P anti-wear booster, aromatic		0.5	0.5	0.5	0.5	0.5	0.5
Corrosion protector		0.09	0.09	0.09	0.09	0.09	0.09
Anti-foam		0.04	0.04	0.04	0.04	0.04	0.04
Sub-total		3.868	3.868	3.503	3.503	3.503	3.503
Oil soluble glyceride of hydroxyl polycarboxylic acid		0	0.5	0.5	0.5	0	0
Oleylamide		0	0.1	0.1	0	0.1	0
Sub-total		0	0.6	0.6	0.5	0.1	0
TOTAL		100.000	100.000	100.000	100.000	100.000	100.000

Example 2

[0124] The samples S1 to S6 were then subjected to anti-wear performance and elastomer compatibility tests. In particular, the FZG and FE8 step 1 and step 2 tests for anti-wear and the NBR and FKM elastomer tests as described above. The post-test oil was checked visually for sludge and there was a surface finish examination carried out with a laser microscope. Results of the tests on the samples S 1 to S6 are set out in Table 3 below.

Table 3: anti-wear performance and elastomer compatibility tests

Sample No:	S1	S2	S3	S4	S5	S6
Anti-wear performance						
FZG	>12	>12	12	-	-	-
FE8 Step 1 wear [mg]	39	5	<1	2	60	26
FE8 Step 2 wear [mg]	-	3	3	-	-	-
FE8 Step 2 sludge	-	None	None	-	-	-
Elastomer compatibility						
NBR 902 [% changes relative to the reference]						
Mass change	0.7	1.6	0.2	0.0	-0.2	-
Volume change	-0.1	1.3	0.1	-0.8	-1.2	-

(continued)

Elastomer compatibility						
NBR 902 [% changes relative to the reference]						
Hardness change	4.3	5	3	4	5	-
Tensile Strength change	-0.3	-3.3	8.0	-3.0	-5.1	-
Rupture Elongation change	-65.8	-64.5	-30.6	-48.3	-52.0	-
Sludge	none	none	none	None	none	-
FKM 585 [% changes relative to the reference]						
Mass change	0.2	0.3	0.2	-	-	-
Volume change	0.7	0.6	0.5	-	-	-
Hardness change	1	1	0.0	-	-	-
Tensile Strength change	-1.8	1.8	5.0	-	-	-
Rupture Elongation change	-8.3	-18.5	-17.8	-	-	-
Sludge	none	none	none	-	-	-
Surface finish						
Ra [nm]	66	34	38	-	-	-
Rz [nm]	738	539	396	-	-	-

[0125] In the later tests carried out (S5 and S6), FZG and other tests were not completed where the FE8 Step 1 wear test demonstrated poor anti-wear performance for use in long-lived robot gear oils.

[0126] A significant improvement in anti-wear can be demonstrated by the inclusion of the oil soluble glyceride of hydroxyl polycarboxylic acid as illustrated by the significant improvement in FE8 Step 1 wear test results for samples S2, S3 and S4 (which contained the oil soluble glyceride of hydroxyl polycarboxylic acid) compared with S 1, S5 and S6 (which did not).

[0127] As can be seen from the data in Table 3, the use of the blend of modified PAO and PAO along with an alkylated naphthalene provides generally adequate elastomer compatibility in all the samples. All the samples were sludge free. Further for each of the samples (where data was obtained), the measures for mass change, volume change and hardness change were within acceptable bounds. Generally very good elastomer compatibility was achieved in sample S3 and significantly better than other samples, such as S2 (differs in proportions of MoDTC and alkylated naphthalene), in terms of rupture elongation change for the NBR elastomer compatibility test as well as tensile strength change. It is clear that formulations such as S2, S3 and S4 having a MoDTC in combination with an oil soluble glyceride of hydroxyl polycarboxylic acid can provide long-lived robot gear oils with very good elastomer compatibility and excellent anti-wear properties, including for gears with a rolling element.

Claims

1. A lubricant composition suitable for use as a lubricant for gearboxes comprising a rolling element, comprising: a base oil composition of lubricating viscosity; and an additive composition comprising a molybdenum dialkyldithiocarbamate and an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or an ester derivative thereof, which lubricant composition has no more than 0.1% by weight of molybdenum dithiophosphate.

2. A lubricant composition as claimed in claim 1, wherein the molybdenum dialkyldithiocarbamate is provided in an amount, in terms of molybdenum, of from 500 to 3000 ppm of the lubricant composition, preferably from 750 to 1500 ppm of the lubricant composition.

3. A lubricant composition as claimed in claim 1 or 2, wherein the oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or ester derivative thereof is provided in an amount of 0.1 to 2.5% by weight of the lubricant composition, preferably 0.25 to 1% by weight of the lubricant composition, and/or the oil-soluble

mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or ester derivative thereof is provided in a percent by weight ratio relative to the molybdenum dialkyldithiocarbamate in the range from 1:3 to 1:1, more preferably in the range 1:2 to 2:3.

4. A lubricant composition as claimed in any one of the preceding claims, in which molybdenum dithiophosphate is absent.

5. A lubricant composition as claimed in any one of the preceding claims, wherein the additive composition further comprises a fatty acid amide having from 12 to 25 carbon atoms, such as oleylamide, in an amount of up to 1% by weight of the lubricant composition.

6. A lubricant composition as claimed in any one of the preceding claims, wherein the additive composition makes up a proportion of the lubricant composition of up to 10% by weight, preferably from 2.5 and 7.5% by weight.

7. A lubricant composition of any one of claims 1 to 6, wherein the base oil composition comprises a functionally modified poly-alpha-olefin, a poly-alpha-olefin and optionally an additive carrier.

8. A lubricant composition as claimed in claim 7, wherein the modified poly-alpha olefin is a poly-alpha-olefin functionalised with an ester group, preferably wherein the modified poly-alpha-olefin is a co-polymer of an alpha-olefin monomer with an ester, preferably wherein the modified poly-alpha-olefin is a co-polymer of an alpha-olefin monomer with an olefinic alkyl ester with a decene olefin chain length and in a ratio of alpha olefin monomer and functionalised monomer in the range 3:2 to 5:1.

9. A lubricant composition as claimed in claim 8, wherein the modified poly-alpha-olefin is a co-polymer of an alpha-olefin monomer with an olefinic anhydride, preferably wherein the olefinic anhydride is an olefinic succinic or maleic anhydride.

10. A lubricant composition as claimed in any one of claims 7 to 9, wherein the poly-alpha-olefin and modified poly-alpha-olefin make up the major part of the base oil composition, preferably at least 75% by weight of the base oil composition.

11. A lubricant composition as claimed in any one of claims 7 to 10, wherein the base oil composition comprises one or more additive carriers.

12. A synthetic gear oil composition suitable for use as a lubricant for gearboxes comprising a rolling element, comprising: a base oil composition comprising a modified poly-alpha olefin; and an additive composition comprising a molybdenum dialkyldithiocarbamate and an oil-soluble mono-, di- or tri-glyceride of at least one hydroxyl polycarboxylic acid, or an ether or ester derivative thereof, which has no more than 0.1% by weight of molybdenum dithiophosphate.

13. Use of a lubricant or gear oil composition as defined in any one of claims 1 to 6 and 12 as a lubricant for gearboxes comprising a rolling element.

14. A method of lubricating a gearbox or operating an apparatus having the gearbox, the gearbox comprising a rolling element, the method comprising supplying to a gearbox comprising a rolling element an oil of lubricating viscosity having the lubricating composition as defined in any one of claims 1 to 6 or 12.

Patentansprüche

1. Eine Schmiermittelzusammensetzung, die als ein Schmiermittel für Getriebe, die einen Wälzkörper beinhalten, geeignet ist, die Folgendes beinhaltet: eine Basisölzusammensetzung mit Schmierviskosität; und eine Additivzusammensetzung, die ein Molybdän-Dialkyldithiocarbamat und ein öllösliches Mono-, Di- oder Triglycerid mindestens einer Hydroxylpolycarbonsäure oder ein Ether- oder ein Esterderivat davon beinhaltet, wobei die Schmiermittelzusammensetzung nicht mehr als 0,1 Gewichts-% Molybdändithiophosphat aufweist.

2. Schmiermittelzusammensetzung nach Anspruch 1, wobei das Molybdän-Dialkyldithiocarbamat in einer Menge, im Hinblick auf Molybdän, von 500 bis 3000 ppm der Schmiermittelzusammensetzung, bevorzugt von 750 bis 1500 ppm der Schmiermittelzusammensetzung, bereitgestellt wird.

3. Schmiermittelzusammensetzung nach Anspruch 1 oder 2, wobei das öllösliche Mono-, Di- oder Triglycerid mindestens einer Hydroxylpolycarbonsäure oder ein Ether- oder Esterderivat davon in einer Menge von 0,1 bis 2,5 Gewichts-% der Schmiermittelzusammensetzung, bevorzugt 0,25 bis 1 Gewichts-% der Schmiermittelzusammensetzung, bereitgestellt wird und/oder das öllösliche Mono-, Di- oder Triglycerid mindestens einer Hydroxylpolycarbonsäure oder ein Ether- oder Esterderivat davon in einem Gewichtsprozentverhältnis relativ zu dem Molybdän-Dialkyldithiocarbamat im Bereich von 1:3 bis 1:1, bevorzugter im Bereich von 1:2 bis 2:3, bereitgestellt wird.

4. Schmiermittelzusammensetzung nach einem der vorhergehenden Ansprüche, in der Molybdän-Dithiophosphat fehlt.

5. Schmiermittelzusammensetzung nach einem der vorhergehenden Ansprüche, wobei die Additivzusammensetzung ferner ein Fettsäureamid mit 12 bis 25 Kohlenstoffatomen, wie etwa Oleylamid, in einer Menge von bis zu 1 Gewichts-% der Schmiermittelzusammensetzung beinhaltet.

6. Schmiermittelzusammensetzung nach einem der vorhergehenden Ansprüche, wobei die Additivzusammensetzung einen Anteil der Schmiermittelzusammensetzung von bis zu 10 Gewichts-%, bevorzugt von 2,5 bis 7,5 Gewichts-%, ausmacht.

7. Schmiermittelzusammensetzung nach einem der Ansprüche 1 bis 6, wobei die Basisölzusammensetzung ein funktionell modifiziertes Polyalphaolefin, ein Polyalphaolefin und optional einen Additivträger beinhaltet.

8. Schmiermittelzusammensetzung nach Anspruch 7, wobei das modifizierte Polyalphaolefin ein mit einer Estergruppe funktionalisiertes Polyalphaolefin ist, wobei das modifizierte Polyalphaolefin bevorzugt ein Copolymer eines Alphaolefinmonomers mit einem Ester ist, wobei das modifizierte Polyalphaolefin bevorzugt ein Copolymer eines Alphaolefinmonomers mit einem olefinischen Alkylester mit einer Decen-Olefinkettenlänge und in einem Verhältnis von Alphaolefinmonomer und funktionalisiertem Monomer im Bereich von 3:2 bis 5:1 ist.

9. Schmiermittelzusammensetzung nach Anspruch 8, wobei das modifizierte Polyalphaolefin ein Copolymer eines Alphaolefinmonomers mit einem olefinischen Anhydrid ist, wobei das olefinische Anhydrid bevorzugt ein olefinisches Bernsteinsäure- oder Maleinsäureanhydrid ist.

10. Schmiermittelzusammensetzung nach einem der Ansprüche 7 bis 9, wobei das Polyalphaolefin und modifizierte Polyalphaolefin den größten Teil der Basisölzusammensetzung, bevorzugt mindestens 75 Gewichts-% der Basisölzusammensetzung, ausmachen.

11. Schmiermittelzusammensetzung nach einem der Ansprüche 7 bis 10, wobei die Basisölzusammensetzung einen oder mehrere Additivträger beinhaltet.

12. Eine synthetische Getriebeölzusammensetzung, die als ein Schmiermittel für Getriebe, die einen Wälzkörper beinhalten, geeignet ist, die Folgendes beinhaltet: eine Basisölzusammensetzung, die ein modifiziertes Polyalphaolefin beinhaltet; und eine Additivzusammensetzung, die ein Molybdän-Dialkyldithiocarbamat und ein öllösliches Mono-, Di- oder Triglycerid mindestens einer Hydroxylpolycarbonsäure oder ein Ether- oder Esterderivat davon beinhaltet, die nicht mehr als 0,1 Gewichts-% von Molybdändithiophosphat aufweist.

13. Verwendung einer Schmiermittel- oder Getriebeölzusammensetzung nach einem der Ansprüche 1 bis 6 und 12 als ein Schmiermittel für Getriebe, die einen Wälzkörper beinhalten.

14. Ein Verfahren zum Schmieren eines Getriebes oder Betreiben einer Vorrichtung, die das Getriebe aufweist, wobei das Getriebe einen Wälzkörper beinhaltet, wobei das Verfahren das Versorgen eines Getriebes, das einen Wälzkörper beinhaltet, mit einem Öl mit Schmierviskosität beinhaltet, das die Schmierzusammensetzung nach einem der Ansprüche 1 bis 6 oder 12 aufweist.

Revendications

1. Composition lubrifiante convenant à une utilisation comme lubrifiant pour boîtes de vitesses comprenant un élément roulant, comprenant : une composition d’huile de base de viscosité lubrifiante ; et une composition d’additif comprenant un dialkyldithiocarbamate de molybdène et un mono-, di- ou triglycéride soluble dans l’huile d’au moins un acide hydroxylpolycarboxylique, ou un dérivé éther ou ester de celui-ci, laquelle composition lubrifiante ne contient

pas plus de 0,1 % en poids de dithiophosphate de molybdène.

2. Composition lubrifiante selon la revendication 1, dans laquelle le dialkyldithiocarbamate de molybdène est présent dans une quantité, en termes de molybdène, de 500 à 3 000 ppm de la composition lubrifiante, préférablement de 750 à 1 500 ppm de la composition lubrifiante.

3. Composition lubrifiante selon la revendication 1 ou 2, dans laquelle le mono-, di- ou triglycéride soluble dans l'huile d'au moins un acide hydroxylpolycarboxylique, ou un dérivé éther ou ester de celui-ci, est présent dans une quantité de 0,1 à 2,5 % en poids de la composition lubrifiante, préférablement de 0,25 à 1 % en poids de la composition lubrifiante, et/ou le mono-, di- ou triglycéride soluble dans l'huile d'au moins un acide hydroxylpolycarboxylique, ou un dérivé éther ou ester de celui-ci, est présent selon un rapport en pourcentage pondéral relativement au dialkyldithiocarbamate de molybdène dans la plage de 1:3 à 1:1, plus préférablement dans la plage de 1:2 à 2:3.

4. Composition lubrifiante selon l'une quelconque des revendications précédentes, dans laquelle le dithiophosphate de molybdène est absent.

5. Composition lubrifiante selon l'une quelconque des revendications précédentes, dans laquelle la composition d'additif comprend en outre un amide d'acide gras comportant de 12 à 25 atomes de carbone, tel que l'oléylamide, dans une quantité de jusqu'à 1 % en poids de la composition lubrifiante.

6. Composition lubrifiante selon l'une quelconque des revendications précédentes, dans laquelle la composition d'additif constitue une proportion de la composition lubrifiante de jusqu'à 10 % en poids, préférablement de 2,5 à 7,5 % en poids.

7. Composition lubrifiante selon l'une quelconque des revendications 1 à 6, dans laquelle la composition d'huile de base comprend une poly-alpha-oléfine fonctionnellement modifiée, une poly-alpha-oléfine et optionnellement un support d'additif.

8. Composition lubrifiante selon la revendication 7, dans laquelle la poly-alpha-oléfine modifiée est une poly-alpha-oléfine fonctionnalisée avec un groupe ester, préférablement dans laquelle la poly-alpha-oléfine modifiée est un copolymère d'un monomère alpha-oléfine avec un ester, préférablement dans laquelle la poly-alpha-oléfine modifiée est un copolymère d'un monomère alpha-oléfine avec un ester alkylique oléfinique ayant une longueur de chaîne oléfinique décène et selon un rapport du monomère alpha-oléfine au monomère fonctionnalisé dans la plage de 3:2 à 5:1.

9. Composition lubrifiante selon la revendication 8, dans laquelle la poly-alpha-oléfine modifiée est un copolymère d'un monomère alpha-oléfine avec un anhydride oléfinique, préférablement dans laquelle l'anhydride oléfinique est un anhydride oléfinique succinique ou maléique.

10. Composition lubrifiante selon l'une quelconque des revendications 7 à 9, dans laquelle la poly-alpha-oléfine et la poly-alpha-oléfine modifiée constituent la majeure partie de la composition d'huile de base, préférablement au moins 75 % en poids de la composition d'huile de base.

11. Composition lubrifiante selon l'une quelconque des revendications 7 à 10, dans laquelle la composition d'huile de base comprend un ou plusieurs supports d'additifs.

12. Composition d'huile synthétique pour engrenages convenant à une utilisation comme lubrifiant pour boîtes de vitesses comprenant un élément roulant, comprenant : une composition d'huile de base comprenant une poly-alpha-oléfine modifiée ; et une composition d'additif comprenant un dialkyldithiocarbamate de molybdène et un mono-, di- ou triglycéride soluble dans l'huile d'au moins un acide hydroxylpolycarboxylique, ou un dérivé éther ou ester de celui-ci, laquelle ne contient pas plus de 0,1 % en poids de dithiophosphate de molybdène.

13. Utilisation d'une composition lubrifiante ou d'une composition d'huile pour engrenages telle que définie dans l'une quelconque des revendications 1 à 6 et 12 comme lubrifiant pour boîtes de vitesses comprenant un élément roulant.

14. Procédé de lubrification d'une boîte de vitesses ou d'utilisation d'un appareil comportant la boîte de vitesses, la boîte de vitesses comprenant un élément roulant, le procédé comprenant l'introduction dans une boîte de vitesses comprenant un élément roulant d'une huile de viscosité lubrifiante comportant la composition lubrifiante telle que définie dans l’une quelconque des revendications 1 à 6 ou 12.

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