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(11) **EP 1 323 816 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.07.2003 Bulletin 2003/27

(21) Application number: **02258378.5**

(22) Date of filing: **04.12.2002**

(51) Int Cl.7: **C10M 163/00**
// (C10M163/00, 129:76,
133:56, 137:10, 159:20),
(C10M163/00, 133:56, 137:10,
159:18, 159:20),
(C10N30/06, 40:25)

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
IE IT LI LU MC NL PT SE SI SK TR**
Designated Extension States:
AL LT LV MK RO

(30) Priority: **21.12.2001 EP 01310820**

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(54) **Heavy duty diesel engine lubricating oil compositions**

(57) The use of an effective amount of one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions in a heavy duty diesel engine lubricating oil composition for improving the fuel economy of a heavy duty diesel engine.

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Description

[0001] The present invention concerns the use of one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions in heavy duty diesel engine lubricating oil compositions. It also relates to such lubricating oil compositions which have been found to give improved fuel economy in operation of heavy duty diesel engines.

[0002] The heavy duty trucking market employs the diesel engine as its preferred power source due to its excellent longevity, and specialized lubricants have been developed to meet the more stringent performance requirements of such heavy duty diesel engines.

[0003] Also, several engine tests are required to demonstrate satisfactory heavy duty performance, including the Cummins M11 test to evaluate soot-related valve train wear, filter plugging and sludge.

[0004] The fuel consumption of heavy duty diesel engines is of great importance to fleet operators since fuel costs constitute up to 30% of operating costs. Use of fuel-efficient lubricating oil compositions would therefore help to reduce fuel consumption: even a 1% reduction would lead to significant cost savings.

[0005] R.I Taylor states in "Heavy Duty Diesel Engine Fuel Economy: Lubricant Sensitivities" 00FL-309, SAE 2000 Millennium Publication "Advances in Powertrain Tribology", SAE 2000, that, because heavy duty diesel engines operate more under hydrodynamic conditions than passenger car engines, friction reducers will not be effective in reducing engine friction losses in heavy duty diesel engines. This conclusion is supported by Stauffer *et al* in Lubrication Engineering, Dec 1984, pp.744-751; and by Kagaya *et al* in SAE 811412.

[0006] It has now been found, in contrast, that friction reducers are effective in improving the fuel economy performance of heavy duty diesel engines.

[0007] Accordingly, in a first aspect the present invention provides the use of an effective amount of one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions in a heavy duty diesel engine lubricating oil composition for improving the fuel economy of a heavy duty diesel engine.

[0008] In a second aspect, the present invention provides a heavy duty diesel engine lubricating oil composition comprising an oil of lubricating viscosity, in a major amount, and added thereto:

(A) an effective amount of one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions;

(B) a minor amount of a detergent composition comprising a metal salt of an aromatic carboxylic acid; and

(C) a minor amount of a dispersant additive;

provided that the lubricating oil composition has a nitrogen content, preferably derived from the dispersant additive, of at least 0.06 mass %, based on the mass of the composition.

[0009] In a third aspect, the present invention provides a heavy duty diesel engine additive concentrate composition comprising a diluent and one or more additives comprising:

(A) one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions;

(B) a detergent composition comprising a metal salt of an aromatic carboxylic acid; and

(C) a dispersant additive;

each in such a proportion as to provide a heavy duty diesel engine lubricating oil composition as defined in the second aspect when the oil composition contains 2 to 20 mass % of the additives.

[0010] In a fourth aspect, the present invention provides combination of a heavy duty diesel engine in a land-based vehicle, which engine has a total displacement of at least 6.5 litres and a displacement per cylinder of at least 1.0 litre per cylinder and a lubricating oil composition as defined in the second aspect.

[0011] In a fifth aspect, the present invention provides a method of lubricating a heavy duty diesel engine in a land-based vehicle, which engine has a total displacement of at least 6.5 litres and a displacement per cylinder of at least 1.0 litre per cylinder, which method comprises supplying to the engine a lubricating oil composition as defined in the second aspect.

[0012] The American Petroleum Institute (API), Association des Constructeur Européen d'Automobile (ACEA) and Japanese Standards Organisation (JASO) specify the performance level required for lubricating oil compositions. Also there are performance specifications known as Global, which contains tests and performance levels from ACEA, API and JASO specifications.

[0013] Thus, a heavy duty lubricating oil composition of the present invention preferably satisfies at least the performance requirements of heavy duty diesel engine lubricants, such as at least the API CF-4 or API CG-4; preferably at least the API CH-4; especially at least the API CI-4. In another embodiment, the lubricating oil composition of the

invention, independently of meeting the API performance requirements, preferably satisfies at least the ACEA E2-96; more preferably at least the ACEA E3-96; especially at least ACEA E4-99; advantageously at least the ACEA E5-99. In a further embodiment, the lubricating oil composition of the invention, independently of meeting the API and ACEA performance requirements, preferably satisfies the JASO DH-1 or Global DHD-1.

[0014] The features of the present invention will now be discussed in more detail.

HEAVY DUTY DIESEL ENGINES

[0015] Heavy duty diesel engines according to the present invention are used in land-based vehicles, preferably large road vehicles, such as large trucks. The road vehicles typically have a weight greater than 12 tonnes. The engines used in such vehicles tend to have a total displacement of at least 6.5, preferably at least 8, more preferably at least 10, such as at least 15, litres; engines having a total displacement of 12 to 20 litres are preferred. Generally, engines having a total displacement greater than 24 litres are not considered land-based vehicles. The engines according to the present invention also have a displacement per cylinder of at least 1.0 or at least 1.5, such as at least 1.75, preferably at least 2, litres per cylinder. Generally, heavy duty diesel engines in road vehicles have a displacement per cylinder of at most 3.5, such as at most 3.0; preferably at most 2.5, litres per cylinder. The term "heavy duty" in relation to internal combustion engines is known in the art: see ASTM D4485 at §3.17 where heavy duty engine operation is characterised by average speeds, power outputs and internal temperatures that are generally close to potential maximums; therefore, a heavy duty diesel engine is considered to operate generally under such conditions.

[0016] As used herein, the terms 'total displacement' and 'displacement per cylinder' are known to those skilled in the art of internal combustion engines (see "Diesel Engine Reference Book", edited by B. Challen and R. Baranescu, second edition, 1999, published by SAE International). Briefly, the term "displacement" corresponds to the volume of the cylinder in the engine as determined by the piston movement and consequently the "total displacement" is the total volume dependent on the number of cylinders; and the term 'displacement per cylinder' is the ratio of the total displacement to the number of cylinders in the engine.

LUBRICATING OIL COMPOSITION

[0017] In each aspect of the invention, the lubricating oil composition preferably has less than 0.13, or less than 0.1, or less than 0.09, or less than 0.08, or less than 0.07 or less than 0.06, mass % of phosphorus based on the mass of the oil composition; more preferably it has at most 0.05, or at most 0.04 or at most 0.03, mass %; such as in the range from 0.001 to 0.03 mass %; for example at most 0.02 or at most 0.01 mass %. In a preferred embodiment of each aspect, the phosphorus content of the lubricating oil composition is zero.

[0018] In each aspect of the invention, the lubricating oil composition preferably has, independently of the amount of phosphorus, at most 1.0, or at most 0.75, or at most 0.50, or at most 0.45, or at most 0.4, or at most 0.35, or at most 0.3, or at most 0.25, mass % of sulfur based on the mass of the oil composition; especially it has at most 0.2 or at most 0.15, mass %; such as in the range from 0.001 to 0.1 mass %. In a preferred embodiment of each aspect, the sulfur content of the lubricating oil composition is zero.

[0019] The amount of phosphorus and sulfur in the lubricating oil composition is each measured according to ASTM D5185.

[0020] In an embodiment of each aspect of the invention, the amount of phosphorus and sulfur is derived from an anti-wear additive, such as a zinc dithiophosphate.

[0021] The lubricating oil composition of the invention can be in the viscometric form of any one of SAE 20W-X, SAE 15W-X, SAE 10W-X, SAE 5W-X and SAE 0W-X, where X represents any one of 20, 30, 40 and 50; the characteristics of the different viscometric grades can be found in the SAE J300 classification. In an embodiment of each aspect of the invention, independently of the other embodiments, the lubricating oil composition is in the form of an SAE 5W-X or SAE 0W-X lubricating oil composition, wherein X represents any one of 20, 30, 40 and 50. Preferably X is 20 or 30.

[0022] It has also found that the lubricating oil compositions of the invention can meet the wear protection needed by heavy duty diesel engines, for example, by satisfying the requirements of the Cummins M11 test to evaluate soot-related valve train wear. Thus, the heavy duty diesel engine lubricating oil compositions of the present invention, particularly low viscosity lubricating oil compositions, such as SAE 5W-X or SAE 0W-X lubricants, where X is as defined above, provide improved fuel economy and also improved wear protection to the heavy duty diesel engine.

[0023] Thus, in a preferred embodiment of each aspect of the present invention, the heavy duty diesel engine lubricating oil composition, preferably in the form of an SAE 5W-X or SAE 0W-X oil composition, comprises one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions, and has a base blend viscosity of at least 8.2, such as from 8.5 to 30, preferably 8.5 to 10, mm²s⁻¹ at 100°C.

[0024] As used herein, the term "base blend viscosity" refers to the viscosity at 100°C, measured according to ASTM D445, of a composition comprising, or an admixture of, components that exhibit Newtonian behaviour, which in the

present invention are all of the components (including the carrier oil such as the basestock) but excluding the solid polymer or 'active ingredient' of the viscosity modifier, which is considered not to exhibit Newtonian behaviour. Thus, the base blend viscosity can refer to the viscosity of a composition comprising basestock oil, dispersant, detergent, ZDDP, antioxidant, all carrier oils and diluent oils of the components, pour depressant and any other components which exhibit Newtonian behaviour, such as anti-foamants.

[0025] Computer modeling systems may also be employed to predict the base blend viscosity of a lubricating oil composition based on the viscosity of the components present therein. Alternatively, the base blend viscosity may be measured by removing the polymer of the viscosity modifier from the lubricating oil composition and then measuring the viscosity of the resulting composition. Alternatively, the base blend viscosity may be determined by measuring the viscosity of the lubricating oil composition at a high shear rate, which shear rate corresponds to the rate that does not affect the viscosity of the oil composition, generally such rates are greater than 10^7 s^{-1} .

[0026] It has been found that lubricating oil compositions having the defined base blend viscosity parameter and one or more of the defined compounds will provide improved fuel economy and pass at least the ACEA E5-99 and/or the API CH-4 specification limits for the Cummins M11 200 hour cross-head wear test.

[0027] In a preferred embodiment of each aspect of the present invention, the oil composition has less than 2 mass % of ash, preferably less than 1.5 mass %, especially less than 1 mass %; such as in the range from 0 to 0.5 mass % ash, according to method ASTM D874.

Oil of Lubricating Viscosity

[0028] The lubricating oil can be a synthetic or mineral oil of lubricating viscosity selected from the group consisting of Group I, II, III, IV or V basestocks and mixtures thereof.

[0029] Basestocks may be made using a variety of different processes including but not limited to distillation, solvent refining, hydrogen processing, oligomerization, esterification and rerefining.

[0030] API 1509 "Engine Oil Licensing and Certification System", Fourteenth Edition, December 1996 states that all basestocks are divided into five general categories:

Group I basestocks contain less than 90% saturates and/or greater than 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120;

Group II basestocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120;

Group III basestocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 120;

Group IV basestocks contain polyalphaolefins (PAO); and

Group V basestocks contain all other basestocks not included in Group I, II, III or IV.

Group IV basestocks, i.e. polyalphaolefins (PAO), include hydrogenated oligomers of an alpha-olefin, the most important methods of oligomerization being free radical processes, Ziegler catalysis, cationic, and Friedel-Crafts catalysis.

[0031] Preferably the lubricating oil is selected from any one of Group I to V basestocks.

[0032] Especially preferred is Group II, III, IV or V basestocks or any two or more mixtures thereof, or mixtures of Group IV basestocks with 5 to 80 mass % of Group I, II, III or V basestocks, such as a fully synthetic mixture of Group IV basestocks and Group V basestocks.

[0033] The test methods used in defining the above groups are ASTM D2007 for saturates; ASTM D2270 for viscosity index; and one of ASTM D2622, 4294, 4927 and 3120 for sulfur.

Compounds

[0034] Compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions, such as in high pressure and sliding contacts, are known as friction reducers and a skilled person would be able to identify such compounds using tests known in the art, for example tests carried out in a high frequency reciprocating rig. Examples of contacts where high pressure and sliding conditions occur are in the valve train, piston ring liners and journal bearings.

[0035] A class of friction reducers is provided by polar compounds that are capable of being adsorbed on metal surfaces, which compounds have a polar head-group and an oleophilic hydrocarbyl chain. These can be broadly divided into two categories, i.e. (A) nitrogen-containing compounds, such as amines, imides and amides, and (B) oxygen-containing compounds, such as fatty acids and full or partial esters thereof.

[0036] The nitrogen-compounds (A) are suitably selected from the group consisting of (i) alkylene amines, especially the monoalkylene diamines, the dialkylene triamines and/or the polyalkylene polyamines, N,N'-dimethyl ethylene diamine which in turn may carry further alkyl and/or hydroxy substituents; (ii) the alkanolamines, especially the N-alkyl derivatives of alkanolamines, such as ethanolamine, propanolamine, isopropanolamine and butanolamine in which the N-alkyl groups have from 1 to 20 carbon atoms, preferably 12 to 18 carbon atoms, the N,N'-dialkanolamines, the N-alkyleneaminoalkyl dialkanolamines, and the di(polyalkyleneoxy) alkanolamines; (iii) the alkyl amides in which the N-alkyl groups have from 1 to 25 carbon atoms, preferably 12 to 22 carbon atoms; and (iv) the alkanolamides, especially the mono- and di-alkanolamides of alkyl carboxylic acids and the (polyalkyleneoxy) alkanolamides. Specific examples of nitrogen-containing organic friction reducers falling into the above categories are:

(i) the monoethylene diamines, diethylene triamines, the triethylene tetraamines and the tetraethylene pentamines, and the N-alkyl derivatives thereof, e.g. Duomeen®T, and N,N'-di(l-hydroxyl-1, 1-dimethyl methyl) ethylene diamine, i.e. Kaneda® No. 6;

(ii) N-alkyl or the appropriate N,N'-dialkyl derivatives of ethanol amines, diethanol amines, propanol amines, isopropanol amines, butanol amines, the N-alkyleneaminoalkyl ethanolamine in which the alkyl group has 10 to 20 carbon atoms, di(polyalkyleneoxy) alkanolamines in which the total number of alkyleneoxy groups may range from 2 to 20, preferably from 5 to 15 groups, especially N-methyl ethanolamine (Kaneda® No.1), N-hydrocarbyl diethanolamine (Kaneda® No. 2B), N, N-dibutyl ethanolamine (Kaneda® No. 4), N-dodecyl diethanolamine (Ethomeen®C12), N-hydrocarbyl diethanolamine (Ethomeen®S12), N-trimethyleneaminoalkyl diethanolamine in which the alkyl group has 12 to 18 carbon atoms (Ethoduomeen®), the N-alkyl-di (polyalkyleneoxy) diethanolamines which respectively have 5, 10 and 15 polyethyleneoxy groups (Tamno®-5, -10 and -15 respectively), and N,N'-dihydroxyethyl ethylenediamine (Kaneda®No.5);

(iii) the alkyl amides in which the alkyl groups have from 1 to 30 carbon atoms, preferably from 5 to 20 carbon atoms and in which the alkyl groups may be straight or branched chain groups, such as Armoslip®CP-P and Armoslip®E in which the alkyl groups have 17 and 21 carbon atoms respectively;

(iv) ethanolamides, the diethanolamides and the (polyalkyleneoxy) ethanolamides, and the N-alkyl derivatives thereof wherein the N-alkyl group has from 1 to 25 carbon atoms, preferably from 5 to 20 carbon atoms and wherein in the case of the (polyalkyleneoxy) ethanolamides said amides having from 5 to 20 polyoxyalkylene groups, such as N-acylethanol amine, e.g. Kaneda® No. 9 (in which the alkyl group in the acyl moiety has 12 carbon atoms), diethanolamines e.g. Amizole® ISDE (in which the alkyl group in the acyl moiety has 18 carbon atoms), Kaneda® No.10 (in which the alkyl group in the acyl moiety has 12 carbon atoms), di(polyethyleneoxy) ethanol amide wherein the acyl group in the acyl moiety has 17 carbon atoms and the total number of polyethyleneoxy groups in the molecule is 5 (e.g. Tamdo®-5).

[0037] Especially preferred examples are compounds of oleic acid and tetraethylene pentamine, ethoxylated tallow amines and ethoxylated tallow ether amines. Also useful are organo-metallic compounds of hydrocarbyl amine compounds, such as disclosed in GB-A-882,295. Amines 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 trialkyl borate.

[0038] Examples of oxygen-containing organic friction reducers (B) are carboxylic acids having 1 to 25 carbon atoms, such as stearic acid and oleic acids, preferably from 12 to 17 carbon atoms; full and partial esters thereof of di- and/or polyhydric alcohols, such as glycerol, trimethylol propane, pentaerythritol and polyhydroxy pyrans; and metal salts thereof, e.g. metal stearates and metal oleates, wherein the metal is selected from transition metals (e.g. zinc), Group 1 metals and Group 2 metals (e.g. calcium). Specific examples of oxygen-containing organic friction reducers (B) are the mono-, di- or tri-esters of glycerol with an alkyl carboxylic acid, such as oleic acid; the corresponding pentaerythritol esters, such as the oleates, especially the mono-oleates; and the monoester of 1-methylenehydroxy-2, 3, 4-trihydroxy pyran, in which the methylene hydroxy group has been esterified with acetic acid. Esters of carboxylic acids and anhydrides with alkanols are described in US 4, 702, 850.

[0039] Examples of other conventional friction reducers are described by M. Belzer in the "Journal of Tribology" (1992), Vol. 114, pp. 675-682 and M. Belzer and S. Jahanmir in "Lubrication Science" (1988), Vol. pp. 3-26.

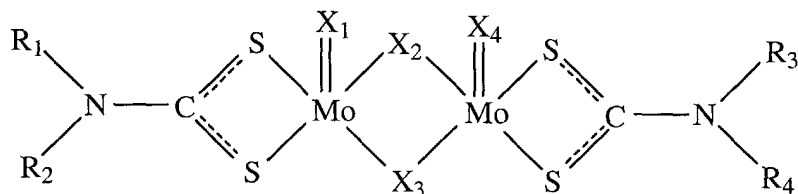
[0040] Oil-soluble additives which deposit molybdenum disulfide are also effective friction reducers, such as oil-

soluble or oil-dispersible molybdenum compounds.

[0041] Examples of organic molybdenum compounds include molybdenum xanthates, thioxanthates, alkoxides, carboxylates (such as, derivatives of polyhydroxy fatty esters, e.g. MOLYVAN® 855), dialkyldithiocarbamates, dialkyldithiophosphinates and dialkyldithiophosphates.

[0042] The molybdenum compound may, for example, be mononuclear, dinuclear, trinuclear or tetranuclear.

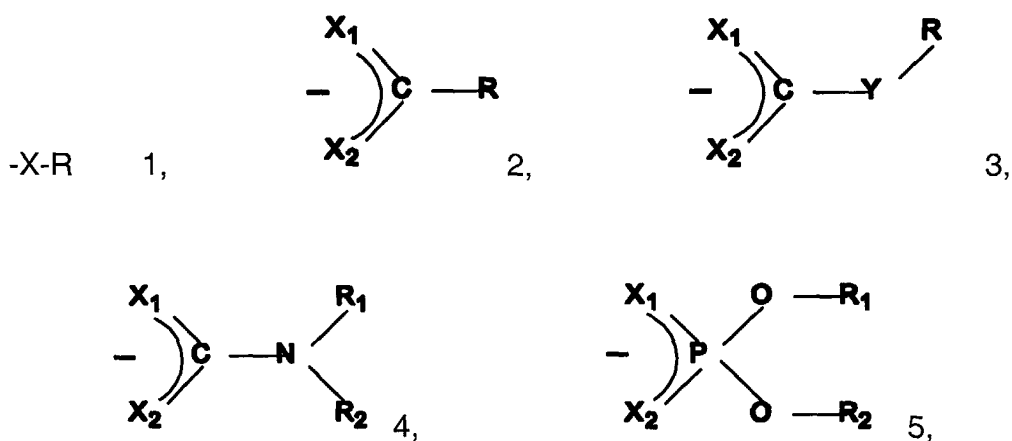
[0043] Dinuclear molybdenum compounds can be represented by the formula $\text{Mo}_2\text{O}_x\text{S}_{4-x}\text{L}_2$, where L is a ligand such as dialkyldithiocarbamate and dialkyldithiophosphate, and x is an integer from 0 to 4. An example of dinuclear (or dimeric) molybdenum dialkyldithiocarbamate is expressed by the following formula:



where R_1 to R_4 independently denote a straight chain, branched chain or aromatic hydrocarbyl group having 1 to 24 carbon atoms; and X_1 to X_4 independently denote an oxygen atom or a sulfur atom. The four hydrocarbyl groups, R_1 to R_4 , may be identical or different from one another.

[0044] Another group of organo-molybdenum compounds useful in the lubricating compositions of this invention are trinuclear (or trimeric) molybdenum compounds, especially those of the formula $\text{Mo}_3\text{S}_k\text{L}_n\text{Q}_z$ and mixtures thereof wherein the L are independently selected ligands having organo groups with a sufficient number of carbon atoms to render the compound soluble in the oil, n is from 1 to 4, k varies from 4 to 7, Q is selected from the group of neutral electron donating compounds such as water, amines, alcohols, phosphines, and ethers, and z ranges from 0 to 5 and includes non-stoichiometric values. At least 21 total carbon atoms should be present among all the ligands' organo groups, such as at least 25, at least 30, or at least 35 carbon atoms.

[0045] The ligands may be selected from the group consisting of



and mixtures thereof, wherein X, X_1 , X_2 , and Y are selected from the group consisting of oxygen and sulfur, and wherein R_1 , R_2 , and R are selected from hydrogen and organo groups that may be the same or different. Preferably, the organo groups are hydrocarbyl groups such as alkyl (e.g. in which the carbon atom attached to the remainder of the ligand is primary or secondary), aryl, substituted aryl and ether groups. More preferably, each ligand has the same hydrocarbyl group.

[0046] The term "hydrocarbyl" as used herein denotes a substituent having carbon atoms directly attached to the remainder of the ligand and is predominantly hydrocarbyl in character. Such substituents include the following:

1. Hydrocarbon substituents, that is, aliphatic (for example alkyl or alkenyl), alicyclic (for example cycloalkyl or cycloalkenyl) substituents, aromatic-, aliphatic- and alicyclic-substituted aromatic nuclei, as well as cyclic substituents wherein the ring is completed through another portion of the ligand (that is, any two indicated substituents

may together form an alicyclic group).

2. Substituted hydrocarbon substituents, that is, those containing non-hydrocarbon groups which do not alter the predominantly hydrocarbyl character of the substituent. Those skilled in the art will be aware of suitable groups (e.g., halo, especially chloro and fluoro, amino, alkoxyl, mercapto, alkylmercapto, nitro, nitroso, sulfoxy, etc.).

[0047] Importantly, the organo groups of the ligands have a sufficient number of carbon atoms to render the compound soluble in the oil. For example, the number of carbon atoms in each group will generally range between 1 to 100, preferably from 1 to 30, and more preferably between 4 to 20. Preferred ligands include dialkyldithiophosphate, alkylxanthate, carboxylates, dialkyldithiocarbamate ("dtc"), and mixtures thereof. Most preferred are the dialkyldithiocarbamates. Those skilled in the art will realize that formation of the compounds of the present invention requires selection of ligands having the appropriate charge to balance the core's charge (as discussed below).

[0048] Compounds having the formula $\text{Mo}_3\text{S}_k\text{L}_n\text{Q}_z$ have cationic cores surrounded by anionic ligands, wherein the cationic cores are represented by structures such as



which have net charges of +4. Electrical neutrality to the trinuclear molybdenum Mo_3S_k species, where k is 4 to 7, is conferred by appropriate choice of anionic and cationic compounds. Four monoanionic ligands, e.g. dithiocarbamate, are preferred. Without wishing to be bound by any theory, it is believed that two or more trinuclear cores may be bound or interconnected by means of one or more ligands and the ligands may be multidentate, i.e., having multiple connections to one or more cores. It is believed that oxygen and/or selenium may be substituted for sulfur in the core(s).

[0049] Oil-soluble trinuclear molybdenum compounds can be prepared by reacting in the appropriate liquid(s)/solvent (s) a molybdenum source such as $(\text{NH}_4)_2\text{Mo}_3\text{S}_{13} \cdot n(\text{H}_2\text{O})$, where n varies between 0 and 2 and includes non-stoichiometric values, with a suitable ligand source such as a tetraalkylthiuram disulfide. Other oil-soluble trinuclear molybdenum compounds can be formed during a reaction in the appropriate solvent(s) of a molybdenum source such as $(\text{NH}_4)_2\text{Mo}_3\text{S}_{13} \cdot n(\text{H}_2\text{O})$, a ligand source such as tetraalkylthiuram disulfide, dialkyldithiocarbamate, or dialkyldithiophosphate, and a sulfur-abstracting agent such as cyanide ions, sulfite ions, or substituted phosphines. Alternatively, a trinuclear molybdenum-sulfur halide salt such as $[\text{M}']_2[\text{Mo}_3\text{S}_7\text{A}_6]$, where M' is a counter ion, and A is a halogen such as Cl, Br, or I, may be reacted with a ligand source such as a dialkyldithiocarbamate or dialkyldithiophosphate in the appropriate liquid(s)/solvent(s) to form an oil-soluble trinuclear molybdenum compound. The appropriate liquid/solvent may be, for example, aqueous or organic.

[0050] The ligand chosen must have a sufficient number of carbon atoms to render the compound soluble in the lubricating composition.

[0051] Trinuclear molybdenum compounds for use in the compositions of this invention can be those of the formula $\text{Mo}_3\text{S}_7((\text{alkyl})_2\text{dtc})_4$ where the alkyl has about 8 to 18 carbon atoms and the alkyl being preferably a "coco" alkyl chain which is a mixture of chains of varying even numbers of carbon atoms from typically a C_8 to C_{18} alkyl, mainly C_{10} , C_{12} and C_{14} alkyls derived from coconut oil.

[0052] Other examples of molybdenum compounds include a sulfurized molybdenum containing composition prepared by (i) reacting an acidic molybdenum compound and a basic nitrogen compound selected from the group consisting of succinimide, a carboxylic acid amide, a hydrocarbyl monoamine, a phosphoramidate, a thiophosphoramidate, a Mannich base, a dispersant viscosity index improver, or a mixture thereof, in the presence of a polar promoter, to form a molybdenum complex, and (ii) reacting the molybdenum complex with a sulfur-containing compound, to thereby form a sulfur- and molybdenum-containing composition.

[0053] In one embodiment of the present invention, the molybdenum compound is preferably dinuclear or trinuclear, more preferably trinuclear.

[0054] In another embodiment of the present invention, the molybdenum compound, irrespective of its nuclearity, is

fully sulfurised, i.e. the core contains only sulfur as the non-metallic element, for example Mo_2S_4 , Mo_3S_4 and Mo_3S_7 .

[0055] In another embodiment of the present invention, the molybdenum compound is preferably a dithiocarbamate compound, such a dinuclear or trinuclear molybdenum dithiocarbamate; especially effective compounds are molybdenum dialkyldithiocarbamate compounds represented by the formula $\text{Mo}_3\text{S}_7((\text{alkyl})_2\text{dtc})_4$.

[0056] Colloidal friction reducers may also be used in the present invention, such as graphite, borate and molybdenum disulfide that are present in the oil composition by dispersion.

[0057] The oil composition may contain a mixture of friction reducers, such as polar compounds that are capable of being adsorbed on a metal surface, whether organic or organo-metallic, and molybdenum compounds.

[0058] In an embodiment, the friction reducer is an organic polar compound having an oleophilic hydrocarbyl chain, such as glycerol monooleate.

[0059] In another embodiment, the friction reducer is a molybdenum compound.

[0060] The friction reducers are present in an amount sufficient to improve the fuel economy of the engine being lubricated. The amount is typically from 0.01 to 5.0, preferably 0.05 to 1.5, more preferably 0.1 or 0.15 to 0.5, mass %, based on the mass of the oil composition.

[0061] In the instance the friction reducer is a molybdenum compound, the lubricating oil composition preferably contains 5 to 5000, more preferably 10 to 1000, especially 50 to 750, for example, 75 to 500, ppm of molybdenum by mass, based on the mass of the oil composition. The amount of molybdenum is measured according to ASTM D5185.

Detergent Composition

[0062] Detergents may also be present in lubricating oil compositions of the present invention.

[0063] A detergent is an additive that reduces formation of piston deposits, for example high-temperature varnish and lacquer deposits, in engines; it has acid-neutralising properties and is capable of keeping finely divided solids in suspension. It is based on metal "soaps", that is metal salts of organic acids, also known as surfactants herein.

[0064] A detergent comprises a polar head, i.e. the metal salt of the organic acid, with a long hydrophobic tail for oil solubility. Therefore, the organic acids typically have one or more functional groups, such as OH or COOH or SO_3H ; and a hydrocarbyl substituent.

[0065] Examples of organic acids include sulphonic acids, phenols and sulphurised derivatives thereof, and carboxylic acids.

[0066] Thus, a detergent composition comprising one or more metal salts of organic acids may be present, for example, a mixture of metal sulfonate and metal phenate.

[0067] It has been found that a detergent composition comprising a metal salt of an aromatic carboxylic acid provides improved performance.

[0068] A preferred detergent composition comprises more than 50 mole % of a metal salt of an aromatic carboxylic acid, based on the moles of the metal salts of organic acids in the detergent composition. Preferably the proportion of the metal salt of an aromatic carboxylic acid is at least 60 or at least 70 mole %; more preferably at least 80 or at least 90 mole %, based on the moles of the metal salts of organic acids in the detergent composition.

[0069] In a most preferred embodiment, the detergent composition comprises 100 mole % of a metal salt of an aromatic carboxylic acid, based on the moles of the metal salts of organic acids in the detergent composition; that is the detergent composition comprises only aromatic carboxylic acids as the organic acids.

[0070] The aromatic moiety of the aromatic carboxylic acid can contain heteroatoms, such as nitrogen and oxygen. Preferably, the moiety contains only carbon atoms; more preferably the moiety contains six or more carbon atoms; for example benzene is a preferred moiety.

[0071] The aromatic carboxylic acid may contain one or more aromatic moieties, such as one or more benzene rings, either fused or connected *via* alkylene bridges.

[0072] The carboxylic moiety may be attached directly or indirectly to the aromatic moiety. Preferably the carboxylic acid group is attached directly to a carbon atom on the aromatic moiety, such as a carbon atom on the benzene ring.

[0073] More preferably, the aromatic moiety also contains a second functional group, such as a hydroxy group or a sulfonate group, which can be attached directly or indirectly to a carbon atom on the aromatic moiety.

[0074] Preferred examples of an aromatic carboxylic acids are salicylic acids and sulphurised derivatives thereof, such as hydrocarbyl substituted salicylic acid and derivatives thereof.

[0075] Processes for sulfurizing, for example a hydrocarbyl-substituted salicylic acid, are similar to those used for phenols, and are well known to those skilled in the art.

[0076] Salicylic acids are typically prepared by carboxylation, for example, by the Kolbe-Schmitt process, of phenoxides, and in that case, will generally be obtained, normally in a diluent, in admixture with uncarboxylated phenol.

[0077] Preferred substituents in oil-soluble salicylic acids are alkyl substituents. In alkylsubstituted salicylic acids, the alkyl groups advantageously contain 5 to 100, preferably 9 to 30, especially 14 to 20, carbon atoms. Where there is more than one alkyl group, the average number of carbon atoms in all of the alkyl groups is preferably at least 9 to

ensure adequate oil-solubility.

[0078] The detergent composition can comprise metal salts of organic acids other than aromatic carboxylic acids, such as sulfonic acids, phenols and sulfurised derivatives thereof, and carboxylic acids. Such organic acids are described in WO 97/46643, which is incorporated herein by reference.

[0079] Each or the metal detergent in the detergent composition may be neutral or overbased, such terms are understood by those skilled in the art.

[0080] The detergents of the present invention may be salts of one type of organic acid or salts of more than one type of organic acids, for example hybrid complex detergents. Preferably, they are salts of one type of organic acid.

[0081] A hybrid complex detergent is where the basic material within the detergent is stabilised by more than one type of organic acid. It will be appreciated by one skilled in the art that a single type of organic acid may contain a mixture of organic acids of the same type. For example, a sulfonic acid may contain a mixture of sulfonic acids of varying molecular weights. Such an organic acid composition is considered as one type. Thus, complex detergents are distinguished from mixtures of two or more separate overbased detergents, an example of such a mixture being one of an overbased calcium salicylate detergent with an overbased calcium phenate detergent.

[0082] The art describes examples of overbased complex detergents. For example, International Patent Application Publication Nos. 97-46643/4/5/6 and 7 describe hybrid complexes made by neutralising a mixture of more than one acidic organic compound with a basic metal compound, and then overbasing the mixture. Individual basic micelles of the detergent are thus stabilised by a plurality of organic acid types. Examples of hybrid complex detergents include calcium phenate-salicylate-sulfonate detergent, calcium phenate-sulfonate detergent and calcium phenate-salicylate detergent.

[0083] EP-A-0 750 659 describes a calcium salicylate phenate complex made by carboxylating a calcium phenate and then sulfurising and overbasing the mixture of calcium salicylate and calcium phenate. Such complexes may be referred to as "phenalates"

[0084] Preferred complex detergents are salicylate-based detergents, for example, a calcium phenate-salicylate-sulfonate detergent and "phenalates".

[0085] In the instance where more than one type of organic acids is present in a single detergent, the proportion of any one type of organic acid to another is not critical, provided the detergent composition comprises the defined proportion of the metal salt of an aromatic carboxylic acid.

[0086] For the avoidance of doubt, the detergent composition may also comprise ashless detergents, i.e. non-metal containing detergents.

[0087] Preferably the detergent composition comprises at least one overbased metal detergent.

[0088] A preferred overbased metal detergent comprises one or more metal salts of aromatic carboxylic acids, preferably one or more metal salts of salicylic acids.

[0089] Group 1 and Group 2 metals are preferred as metals in the detergents; more preferably calcium and magnesium, especially calcium is preferred.

[0090] Detergent compositions comprising at least one calcium salicylate-based detergent, preferably at least one overbased calcium salicylate-based detergent, have been found to be particularly effective in the present invention.

[0091] Applicant, therefore, considers that detergent compositions comprising only calcium salicylate-based detergents, whether neutral or overbased, would be advantageous.

[0092] Preferably, the detergent composition is present in the oil composition in an amount, based on surfactant content, of at least 5, preferably at least 10, such as at least 20 or at least 30, more preferably at least 50, most especially at most 75, millimoles of surfactant per kilogram of the oil composition (mmol/kg). In an embodiment, the amount of detergent composition, based on surfactant content, in the oil composition is 10 to 15 mmol/kg.

[0093] Means for determining the amount of surfactant and the amount of metal salt of an aromatic carboxylic acid are known to those skilled in the art. For example, a skilled person can calculate the amounts in the final lubricating oil composition from information concerning the amount of raw materials (e.g. organic acids) used to make the detergent(s) and from information concerning the amount of detergent(s) used in the final oil composition. Analytical methods (e.g. potentiometric titration and chromatography) can also be used to determine the amounts of surfactant and metal salt of an aromatic carboxylic acid.

[0094] It will be appreciated by a skilled person in the art that the methods to determine the amount of metal salts of organic acids (also known as surfactants), including the amount of metal salts of aromatic carboxylic acids, are at best approximations and that differing methods will not always give exactly the same result; they are, however, sufficiently precise to allow the practice of the present invention.

Dispersant Additive

[0095] Dispersant additives maintain oil-insoluble substances, resulting from oxidation during use, in suspension in the fluid, thus preventing sludge flocculation and precipitation or deposition on metal parts. So-called ashless disper-

sants are organic materials which form substantially no ash on combustion, in contrast to metal-containing (and thus ash-forming) detergents. Borated metal-free dispersants are also regarded herein as ashless dispersants. Suitable dispersants include, for example, derivatives of long chain hydrocarbyl-substituted carboxylic acids, in which the hydrocarbyl group has a number average molecular weight of less than 15,000, such as less than 5000; examples of such derivatives being derivatives of high molecular weight hydrocarbyl-substituted succinic acid. Such hydrocarbyl-substituted carboxylic acids may be reacted with, for example, a nitrogen-containing compound, advantageously a polyalkylene polyamine, or with an alcohol. Particularly preferred dispersants are the reaction products of polyalkylene amines with alkenyl succinic anhydrides. Examples of specifications disclosing dispersants of the last-mentioned type are US-A-3 202 678, 3 154 560, 3 172 892, 3 024 195, 3 024 237, 3 219 666, 3 216 936 and BE-A-662 875.

[0096] Alternatively or in addition, dispersancy may be provided by polymeric compounds capable of providing viscosity index improving properties and dispersancy, such compounds are known as multifunctional viscosity index improvers. Such polymers differ from conventional viscosity index improvers in that they provide performance properties, such as dispersancy and/or antioxidancy, in addition to viscosity index improvement.

[0097] Dispersant olefin copolymers and dispersant polymethacrylates are examples of multifunctional viscosity index improvers. Multifunctional viscosity index improvers are prepared by chemically attaching various functional moieties, for example amines, alcohols and amides, onto polymers, which polymers preferably tend to have a number average molecular weight of at least 15,000, such in the range from 20,000 to 600,000, as determined by gel permeation chromatography or light scattering methods. The polymers used may be those described above with respect to viscosity modifiers. Therefore, amine molecules may be incorporated to impart dispersancy and/or antioxidancy characteristics, whereas phenolic molecules may be incorporated to improve antioxidant properties. A specific example, therefore, is an inter-polymer of ethylene-propylene post grafted with an active monomer such as maleic anhydride and then derivatized with, for example, an alcohol or amine.

[0098] EP-A-24146 and EP-A-0 854 904 describe examples of dispersants and dispersant viscosity index improvers, which are accordingly incorporated herein.

[0099] Heavy duty diesel engine lubricating oil compositions tend to require higher amount of dispersant than for example a passenger car engine oil composition because more oil-insoluble substances, such as soot, are formed in heavy duty diesel engines. Accordingly, the amount of a dispersant additive, whether in the form of a dispersant additive and/or a multifunctional viscosity index improver additive, in a heavy duty diesel engine lubricating oil composition is, based on nitrogen, preferably at least 0.06, more preferably at least 0.09, especially at least 0.12, mass %, based on the mass of the oil composition. The amount of nitrogen derived from the dispersant tends not to be more than 0.2 mass %.

[0100] In every instance the oil composition has an amount of phosphorus less than 0.09 mass %, based on the mass of the oil composition, and the oil composition does not contain a dispersant viscosity index improver additive, the amount of nitrogen in the oil composition is preferably at least 0.045, more preferably 0.5, such at least 0.055, advantageously at least 0.06, especially at least 0.065, such as at least 0.08, for example, at least 0.1, mass %, based on the mass of the oil composition. The amount of nitrogen is preferably at most 0.3, such as at most 0.25 or at most 0.2, mass %, based on the mass of the oil composition. The amount of nitrogen is measured according to ASTM D4629. Preferably, the amount of nitrogen is derived from a dispersant additive, such as a polyisobutenyl succinimide. In the event a dispersant viscosity index improver additive is present in the lubricating oil composition, then amount of nitrogen can be lower than 0.045 mass %, for example, from 0.001 to 0.04 mass % based on the mass of the oil composition. In a preferred embodiment, the amount of nitrogen, irrespective of whether the oil composition contains dispersant viscosity index improver additive or not, is at least 0.045 mass %. In the instance the oil composition contains a dispersant viscosity index improver additive, the amount of the additive is preferably 0.01 to 5, preferably 0.05 to 3, especially 0.1 to 2, mass %, based on the mass of the oil composition.

Co-additives

[0101] Other additives may also be present in the oil composition of the present invention.

[0102] Co-additives suitable in the present invention include viscosity index improvers, corrosion inhibitors, other oxidation inhibitors or antioxidants, rust inhibitors or rust prevention agents, anti-wear agents, pour point depressants, demulsifiers, and anti-foaming agents.

[0103] Viscosity index improvers (or viscosity modifiers) impart high and low temperature operability to a lubricating oil and permit it to remain shear stable at elevated temperatures and also exhibit acceptable viscosity or fluidity at low temperatures. Suitable compounds for use as viscosity modifiers are generally high molecular weight hydrocarbon polymers, including polyesters, such as polymethacrylates; poly(ethylene-co-propylene) polymers and closely related modifications (so called olefin copolymers); hydrogenated poly(styrene-co-butadiene or -isoprene) polymers and modifications; and esterified poly(styrene-co-maleic anhydride) polymers. Oil-soluble viscosity modifying polymers generally have number average molecular weights of at least 15,000 to 1,000,000, preferably 20,000 to 600,000, as deter-

mined by gel permeation chromatography or light scattering methods. The disclosure in Chapter 5 of "Chemistry & Technology of Lubricants", edited by R.M. Mortier and S.T. Orzulik, First edition, 1992, Blackie Academic & Professional, is incorporated herein.

[0104] Corrosion inhibitors reduce the degradation of metallic parts contacted by the lubricating oil composition. Thiadiazoles, for example those disclosed in US-A-2 719 125, 2 719 126 and 3 087 932 are examples of corrosion inhibitors for lubricating oils.

[0105] Oxidation inhibitors, or antioxidants, reduce the tendency of mineral oils to deteriorate in service, evidence of such deterioration being, for example, the production of varnish-like deposits on metal surfaces and of sludge, and viscosity increase. Suitable oxidation inhibitors include sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof; hindered phenols; diphenylamines; phenyl-naphthylamines; and phosphosulfurized or sulfurized hydrocarbons.

[0106] Other oxidation inhibitors or antioxidants which may be used in lubricating oil compositions include oil-soluble copper compounds. The copper may be blended into the oil as any suitable oil-soluble copper compound. By oil-soluble it is meant that the compound is oil-soluble under normal blending conditions in the oil or additive package. The copper may, for example, be in the form of a copper dihydrocarbyl thio- or dithio-phosphate. Alternatively, the copper may be added as the copper salt of a synthetic or natural carboxylic acid, for example, a C₈ to C₁₈ fatty acid, an unsaturated acid, or a branched carboxylic acid. Also useful are oil-soluble copper dithiocarbamates, sulfonates, phenates, and acetylacetonates. Examples of particularly useful copper compounds are basic, neutral or acidic copper Cu^I and/or Cu^{II} salts derived from alkenyl succinic acids or anhydrides.

[0107] Copper antioxidants will generally be employed in an amount of from about 5 to 500 ppm by weight of the copper, in the final lubricating composition.

[0108] Rust inhibitors selected from the group consisting of nonionic polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, and anionic alkyl sulfonic acids may be used.

[0109] Antiwear agents, as their name implies, reduce wear of metal parts. Zinc dihydrocarbyl dithiophosphates (ZDDPs) are very widely used as antiwear agents. Examples of ZDDPs for use in oil-based compositions are those of the formula Zn[SP(S)(OR¹)(OR²)]₂ wherein R¹ and R² contain from 1 to 18, and preferably 2 to 12, carbon atoms.

[0110] Sulfur- and molybdenum-containing compounds are also examples of anti-wear additives. Also suitable are ashless phosphorus- and sulfur-containing compounds.

[0111] Pour point depressants, otherwise known as lube oil flow improvers, lower the minimum temperature at which the fluid will flow or can be poured. Such additives are well known. Foam control may be provided by an antifoamant of the polysiloxane type, for example, silicone oil or polydimethyl siloxane.

[0112] A small amount of a demulsifying component may be used. A preferred demulsifying component is described in EP-A-0 330 522. It is obtained by reacting an alkylene oxide with an adduct obtained by reacting a bis-epoxide with polyhydric alcohol.

[0113] Some of the above-mentioned additives may provide a multiplicity of effects; thus for example, a single additive may act as a dispersant-oxidation inhibitor. This approach is well known and need not be further elaborated herein.

[0114] Preferably an anti-wear additive, such a metal dihydrocarbyldithiophosphate, for example, zinc dihydrocarbyldithiophosphate, is present in the lubricating oil compositions of the present invention.

[0115] When lubricating compositions contain one or more of the above-mentioned additives, including the detergents, each additive is typically blended into the base oil in an amount which enables the additive to provide its desired function. Representative effective amounts of such additives, when used in lubricants, are as follows:

Additive	Mass % a.i.* (Broad)	Mass % a.i.* (Preferred)
Viscosity Modifier	0.01-6	0.01-4
Corrosion Inhibitor	0.01-5	0.01-1.5
Oxidation Inhibitor	0.01-5	0.01-1.5
Friction Reducer	0.01-5	0.01-1.5
Dispersant	0.1-20	0.1-8
Dispersant Viscosity Modifier	0.01 -5	0.05-5
Detergent	0.01-6	0.01-3
Anti-wear Agent	0.01-6	0.01-4
Pour Point Depressant	0.01-5	0.01-1.5
Rust Inhibitor	0.001-0.5	0.01-0.2

* Mass % active ingredient based on the final lubricating oil composition.

(continued)

Additive	Mass % a.i.* (Broad)	Mass % a.i.* (Preferred)
Anti-Foaming Agent	0.001-0.3	0.001-0.15
Demulsifier	0.001-0.5	0.01-0.2

* Mass % active ingredient based on the final lubricating oil composition.

[0116] The additives may be incorporated into a base oil in any convenient way. Thus, each of the additive can be added directly to the oil by dispersing or dissolving it in the oil at the desired level of concentration. Such blending may occur at ambient temperature or at an elevated temperature.

[0117] When a plurality of additives are employed it may be desirable, although not essential, to prepare one or more additive packages (also known as additive compositions or concentrates) comprising the additives, whereby several additives, with the exception of viscosity modifiers, multifunctional viscosity modifiers and pour point depressants, can be added simultaneously to the base oil to form the lubricating oil composition. Dissolution of the additive package(s) into the lubricating oil may be facilitated by diluent or solvents and by mixing accompanied with mild heating, but this is not essential. The additive package(s) will typically be formulated to contain the additive(s) in proper amounts to provide the desired concentration in the final formulation when the additive package(s) is/are combined with a predetermined amount of basestock. The nitrogen content of such an additive concentrate is generally in the range of 0.5 to 1.5, preferably in the range of 0.7 to 1.0, mass %, based on the mass of the additive concentrate. Thus, one or more detergents may be added to small amounts of base oil or other compatible solvents (such as a carrier oil or diluent oil) together with other desirable additives to form additive packages containing active ingredients in an amount, based on the additive package, of, for example, from 2.5 to 90 mass %, and preferably from 5 to 75 mass %, and most preferably from 8 to 60 mass %, of additives in the appropriate proportions with the remainder being diluent. The final formulations may typically contain 5 to 40 mass % of the additive package(s), the remainder being diluent.

[0118] The amount of additives in the final lubricating oil composition is generally dependent on the type of the oil composition, for example, a heavy duty diesel engine lubricating oil composition has 2 to 20, preferably 5 to 18, more preferably 7 to 16, such as 8 to 14, mass % of additives based on the mass of the oil composition.

[0119] Thus, a method of preparing the oil composition according to the present invention can involve admixing an oil of lubricating viscosity and one or more of the defined compounds or an additive package that comprises one or more of the defined compounds.

[0120] It should be appreciated that interaction may take place between any two or more of the additives, including any two or more detergents, after they have been incorporated into the oil composition. The interaction may take place in either the process of mixing or any subsequent condition to which the composition is exposed, including the use of the composition in its working environment. Interactions may also take place when further auxiliary additives are added to the compositions of the invention or with components of oil. Such interaction may include interaction which alters the chemical constitution of the additives. Thus, the compositions of the invention include compositions in which interaction, for example, between any of the additives, has occurred, as well as compositions in which no interaction has occurred, for example, between the components mixed in the oil.

In this specification:

[0121] The term "comprising" or "comprises" when used herein is taken to specify the presence of stated features, integers, steps or components, but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

[0122] The term "oil-soluble" or "oil-dispersible", as used herein, does not mean that the additives are soluble, dispersible, miscible or capable of being suspended in the oil in all proportions. They do mean, however, that the additives are, for instance, soluble or stable dispersible in the oil to an extent sufficient to exert their intended effect in the environment in which the oil composition is employed. Moreover, the additional incorporation of other additives such as those described above may affect the solubility or dispersibility of the additives.

[0123] "Major amount" means in excess of 50 mass % of the composition.

[0124] "Minor amount" means less than 50 mass % of the composition, both in respect of the stated additive and in respect of the total mass % of all of the additives present in the composition, reckoned as active ingredient of the additive or additives.

[0125] "TBN" is Total Base Number as measured by ASTM D2896.

[0126] All percentages reported are mass % on an active ingredient basis, i.e., without regard to carrier or diluent oil, unless otherwise stated.

[0127] The abbreviation SAE stands for Society of Automotive Engineers, who classify lubricants by viscosity grades.

[0128] The invention is illustrated by, but in no way limited to, the following examples.

Examples

[0129] Lubricating oil compositions were blended by known methods so that each composition was an SAE 5W30 lubricating oil composition. Each oil composition comprised a detergent composition containing salicylate detergents; a zinc dihydrocarbyl dithiophosphate; and a borated dispersant. Thus, each oil composition was comparable to one another because they contained identical additives with the exception of Example 1 and Example 2, which also contained a friction reducer: Example 1 contained as a friction reducer a glycerol monooleate in an amount of 0.3 mass %, while Example 2 contained as a friction reducer a trinuclear molybdenum dithiocarbamate in an amount of 450 ppm of molybdenum.

[0130] The lubricating oil compositions (Comparative Example A, Example 1 and Example 2) were tested for fuel economy in a total driveline rig which comprised a Volvo FH-12 litre heavy duty diesel engine, together with a transmission including a gearbox and an axle.

[0131] The rig is based upon extensive use of electronic engine management systems, which allows the connection of transmission and to a certain degree transaxles via CAN (Controlled Area Network) as a total driveline rig. This rig is described in "Neues F&E-Zentrum für Antriebsstrang-Schmierung" by Peter Ahrweiler and Gerd Rentel, ATZ Automobiletechnische Zeitschrift, 100 (1998), 3, pages 202 - 209. One of the major benefits of the total driveline rig is in the form of reduced error of measurement of heavy duty diesel fuel economy. Removal of error sources associated with fleet trials such as driver variation, tyre pressure variation, drive cycle variation and aerodynamic variation is essential if accurate fuel economy measurements are to be made. This is now possible using the total driveline rig. Historical data has shown that fuel economy measurements of greater than 0.29% are real at the 95% confidence interval.

[0132] The fuel economy measurements are quoted as an improvement, in percentage, compared to a lubricating oil composition having the same additive components as Comparative Example A, but blended to an SAE 15W40 grade.

[0133] Table 1 summarises the results obtained and shows that the use of friction reducers in heavy duty diesel engine lubricating oil compositions provides an improvement in the fuel economy of the engine: the improvement is about double that achieved by the oil composition not containing a friction reducer (compare Comparative Example A with Example 1 or Example 2). Table 1 also provides certain properties of the oil compositions.

Table 1:

	Comparative Example A	Example 1	Example 2
SAE J300 classification	5W30	5W30	5W30
Phosphorus, % mass (ASTM D5185)	0.12	0.13	0.12
Sulfur, % mass (ASTM D5185)	0.33	0.34	0.41
Nitrogen, mass %	0.10	0.10	0.11
Base blend viscosity @ 100 °C, mm ² s ⁻¹	8.83	8.80	8.89
Improvement in Fuel Economy, % ¹	0.69 ²	1.50	1.35

¹ – percentage improvement in fuel economy relative to a lubricating oil composition blended to an SAE 15W40 grade; ² – average of two measurements

Claims

1. The use of an effective amount of one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions in a heavy duty diesel engine lubricating oil composition for improving the fuel economy of a heavy duty diesel engine.

2. A heavy duty diesel engine lubricating oil composition comprising an oil of lubricating viscosity, in a major amount, and added thereto:

(A) an effective amount of one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions;

(B) a minor amount of a detergent composition comprising a metal salt of an aromatic carboxylic acid; and

(C) a minor amount of a dispersant additive;

provided that the lubricating oil composition has a nitrogen content of at least 0.06 mass %, based on the mass of the composition.

3. The oil composition of claim 2, wherein the oil composition satisfies at least the API CG-4 performance specification and/or the ACEA E2-96 performance specification.

4. The oil composition of either claim 2 or claim 3 in the form of an SAE 5W-X or SAE 0W-X lubricating oil composition, where X is any one of 20, 30, 40 and 50.

5. The oil composition of any one of claims 2 to 4, wherein the base blend viscosity of the composition is at least 8.2 mm²s⁻¹ at 100°C.

6. The oil composition of any one of claims 2 to 5, wherein the or at least one of the compounds has a polar head-group and an oleophilic hydrocarbyl chain.

7. The oil composition of any one of claims 2 to 5, wherein the or at least one of the compounds is a molybdenum compound.

8. A heavy duty diesel engine additive concentrate composition comprising a diluent and one or more additives comprising:

(A) one or more compounds capable of reducing friction coefficients under mixed lubrication or boundary lubrication conditions;

(B) a detergent composition comprising a metal salt of an aromatic carboxylic acid; and

(C) a dispersant additive;

each in such a proportion as to provide a heavy duty diesel engine lubricating oil composition as defined in claim 2 when the oil composition contains 2 to 20 mass % of the additives.

9. A combination of a heavy duty diesel engine in a land-based vehicle, which engine has a total displacement of at least 6.5 litres and a displacement per cylinder of at least 1.0 litre per cylinder and a lubricating oil composition as defined in any one of claims 2 to 7.

10. A method of lubricating a heavy duty diesel engine in a land-based vehicle, which engine has a total displacement of at least 6.5 litres and a displacement per cylinder of at least 1.0 litre per cylinder, which method comprises supplying to the engine a lubricating oil composition as defined in any one of claims 2 to 7.



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EUROPEAN SEARCH REPORT

Application Number
EP 02 25 8378

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 6 010 987 A (PICTROSKI CHARLES FREDERICK ET AL) 4 January 2000 (2000-01-04) * column 2, line 59 - column 3, line 11 * * column 4, line 56-65; claim 1 * * column 5, line 1-4 * ---	1-5,7-10	C10M163/00 /(C10M163/00, 129:76,133:56, 137:10, 159:20), (C10M163/00, 133:56,137:10, 159:18, 159:20), C10N30:06, 40:25
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The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 9 April 2003	Examiner Kazemi, P
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)



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EUROPEAN SEARCH REPORT

Application Number
EP 02 25 8378

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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Place of search MUNICH		Date of completion of the search 9 April 2003	Examiner Kazemi, P
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