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(54) **MOTORCYCLE LUBRICANT**

(57) It has been found that the balance between friction reduction in the engine crankcase and the maintenance of sufficient friction in the clutch assembly of a 4T motorcycle, where the engine crankcase and the clutch assembly are lubricating by the same lubricating oil composition from a common sump, can be achieved by use of a lubricating oil composition comprising a combination of molybdenum containing additive and ashless organic friction modifier.

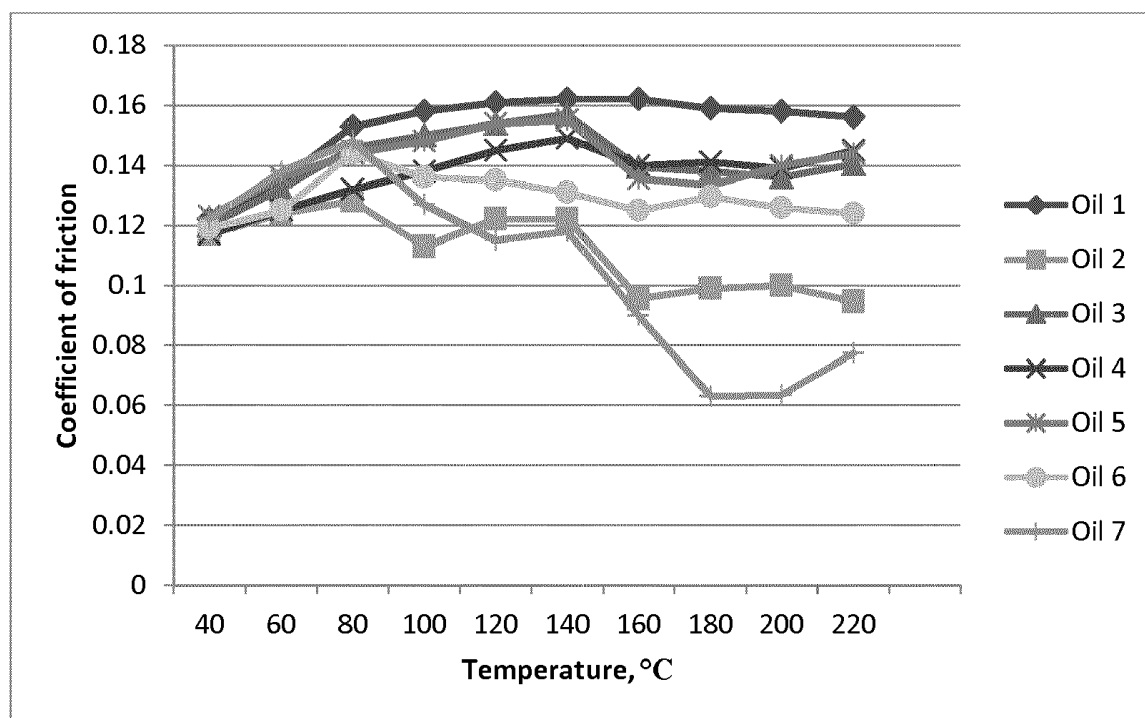


Fig. 1

Description**FIELD OF THE INVENTION**

[0001] The present invention relates to a motorcycle having a four cycle engine and a transmission including a clutch assembly, the engine crankcase and the clutch assembly being lubricated by a lubricating oil provided from a common sump, and lubricating oil compositions suitable for lubricating the engine crankcase and clutch assembly of such motorcycles.

BACKGROUND OF THE INVENTION

[0002] In a typical motorcycle, a common sump lubricates the engine, transmission and wet clutch. Such universal lubricating fluids as used in motorcycles, therefore, must have a balance of both desirable friction properties and lubricity properties. In particular, whilst it is desirable to reduce friction in the engine crankcase to improve fuel economy it is important to maintain sufficient friction in the clutch assembly to allow it to function efficiently.

[0003] It is well known to use molybdenum-containing additives as friction modifiers in crankcase lubricants for passenger car engine oils. However, use of molybdenum-containing additives in motorcycle lubricants is problematic due to the need to maintain sufficient friction in the clutch assembly.

[0004] This problem was considered in International patent application number WO 2015/195614, which discloses a method of operating a 4-stroke motorcycle engine comprising supplying to the engine and clutch a lubricant comprising (a) an antimony dialkyldithiocarbamate compound and (b) an ash-free friction modifier comprising at least one of long chain fatty acid derivatives of amines, long chain fatty esters, derivatives of long chain fatty epoxides, fatty imidazolines; amine salts of alkylphosphoric acids or fatty esters amides or imides of hydroxyl-carboxylic acids, wherein the lubricating composition comprise less than 50 weight percent of a synthetic ester having a kinematic viscosity of 5.5 to 25 mm²/s when measured at 100°C. The lubricant of WO 2015/195614 may also comprise a N-containing molybdenum additive other than a molybdenum dithiocarbamate, which latter may result in undesirable friction properties.

[0005] However, it has been discovered that a lubricant comprising molybdenum additives, including, but not limited to molybdenum dithiocarbamate complexes, can be successfully used to lubricate the engine crankcase and the clutch assembly from a common sump of a motorcycle having a four cycle engine by including an ash-free friction modifier in the lubricant.

SUMMARY OF THE INVENTION

[0006] According to a first aspect the present invention provides a motorcycle having a four cycle engine and a transmission including a clutch assembly, the engine crankcase and the clutch assembly being lubricated by a lubricating oil composition provided from a common sump, wherein said lubricating oil composition comprises a major amount of oil of lubricating viscosity and minor amounts of (A) an oil soluble molybdenum compound and (B) an ashless organic friction modifier.

[0007] According to a second aspect the present invention further provides a method of operating a motorcycle having a four cycle engine and a transmission including a clutch assembly, the engine crankcase and the clutch assembly being lubricated by a lubricating oil composition provided from a common sump, said method comprising supplying to the engine crankcase and clutch assembly a lubricating oil composition comprising a major amount of oil of lubricating viscosity and minor amounts of (A) an oil soluble molybdenum compound and (B) an ashless organic friction modifier.

[0008] According to a third aspect the present invention also provides a lubricating oil composition comprising a major amount of oil of lubricating viscosity and minor amounts of (A) an oil soluble molybdenum compound and (B) an ashless organic friction modifier, which lubricating oil composition exhibits a JASO clutch friction of at least MA1 when measured according to the JASO T 903:2016 clutch friction test. In a preferred embodiment the lubricating oil composition of the third aspect of the invention exhibits a JASO clutch friction of at MA2 when measured according to the JASO T 903:2016 clutch friction test.

[0009] According to a fourth aspect the present invention provides the use of a combination of (A) an oil soluble molybdenum compound and (B) an ashless organic friction modifier in a lubricating oil composition to achieve at least an MA1 in the JASO T 903:2016 clutch friction test.

[0010] In this specification, the following words and expressions, if and when used, have the meanings given below:

"active ingredients" or "(a.i.)" refers to additive material that is not diluent or solvent;

"comprising" or any cognate word specifies the presence of stated features, steps, or integers or components, but does not preclude the presence or addition of one or more other features, steps, integers, components or groups thereof. The expressions "consists of", or "consists essentially of" or cognates may be embraced within "comprises"

or cognates, wherein "consists essentially of" permits inclusion of substances not materially affecting the characteristics of the composition to which it applies;

"hydrocarbyl" means a chemical group of a compound that contains hydrogen and carbon atoms and that is bonded to the remainder of the compound directly via a carbon atom. The group may contain one or more atoms other than carbon and hydrogen provided they do not affect the essentially hydrocarbyl nature of the group. Those skilled in the art will be aware of suitable groups (e.g., halo, especially chloro and fluoro, amino, alkoxy, mercapto, alkylmercapto, nitro, nitroso, sulfoxy, etc.). Preferably, the group consists essentially of hydrogen and carbon atoms, unless specified otherwise. Preferably, the hydrocarbyl group comprises an aliphatic hydrocarbyl group. The term "hydrocarbyl" includes "alkyl", "alkenyl", "allyl" and "aryl" as defined herein;

"alkyl" means a C₁ to C₃₀ alkyl group which is bonded to the remainder of the compound directly via a single carbon atom. Unless otherwise specified, alkyl groups may, when there are a sufficient number of carbon atoms, be linear (i.e. unbranched) or branched, be cyclic, acyclic or part cyclic/acyclic. Preferably, the alkyl group comprises a linear or branched acyclic alkyl group. Representative examples of alkyl groups include, but are not limited to, methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, iso-butyl, tert-butyl, n-pentyl, iso-pentyl, neo-pentyl, hexyl, heptyl, octyl, dimethyl hexyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, nonadecyl, icosyl and triacontyl;

"aryl" means a C₆ to C₁₈, preferably C₆ to C₁₀, aromatic group, optionally substituted by one or more alkyl groups, halo, hydroxyl, alkoxy and amino groups, which is bonded to the remainder of the compound directly via a single carbon atom. Preferred aryl groups include phenyl and naphthyl groups and substituted derivatives thereof, especially phenyl and alkyl substituted derivatives thereof;

"alkenyl" means a C₂ to C₃₀, preferably a C₂ to C₁₂, group which includes at least one carbon to carbon double bond and is bonded to the remainder of the compound directly via a single carbon atom, and is otherwise defined as "alkyl";

"alkylene" means a C₂ to C₂₀, preferably a C₂ to C₁₀, more preferably a C₂ to C₆ bivalent saturated acyclic aliphatic radical which may be linear or branched. Representative examples of alkylene include ethylene, propylene, butylene, isobutylene, pentylene, hexylene, heptylene, octylene, nonylene, decylene, 1-methyl ethylene, 1-ethyl ethylene, 1-ethyl-2-methyl ethylene, 1,1-dimethyl ethylene and 1-ethyl propylene;

"polyol" means an alcohol which includes two or more hydroxyl functional groups (i.e. a polyhydric alcohol) but excludes a "polyalkylene glycol" (component B(ii)) which is used to form the oil-soluble or oil-dispersible polymeric friction modifier. More specifically, the term "polyol" embraces a diol, triol, tetrol, and/or related dimers or chain extended polymers of such compounds. Even more specifically, the term "polyol" embraces glycerol, neopentyl glycol, trimethylolethane, trimethylolpropane, trimethylolbutane, pentaerythritol, dipentaerythritol, tripentaerythritol and sorbitol;

"polycarboxylic acid" means an organic acid, preferably a hydrocarbyl acid, which includes 2 or more carboxylic acid functional groups. The term "polycarboxylic acid" embraces di-, tri- and tetra- carboxylic acids;

"halo" or "halogen" includes fluoro, chloro, bromo and iodo;

"oil-soluble" or "oil-dispersible", or cognate terms, used herein do not necessarily indicate that the compounds or additives are soluble, dissolvable, miscible, or are capable of being suspended in the oil in all proportions. These do mean, however, that they are, for example, soluble or stably dispersible in oil to an extent sufficient to exert their intended effect in the environment in which the oil is employed. Moreover, the additional incorporation of other additives may also permit incorporation of higher levels of a particular additive, if desired;

"ashless" in relation to an additive means the additive does not include a metal;

"ash-containing" in relation to an additive means the additive includes a metal;

"major amount" means in excess of 50 mass % of a composition expressed in respect of the stated component and in respect of the total mass of the composition, reckoned as active ingredient of the component;

"minor amount" means less than 50 mass % of a composition, expressed in respect of the stated additive and in respect of the total mass of the composition, reckoned as active ingredient of the additive;

"effective minor amount" in respect of an additive means an amount of such an additive in a lubricating oil composition so that the additive provides the desired technical effect;

"ppm" means parts per million by mass, based on the total mass of the lubricating oil composition;

"metal content" of the lubricating oil composition or of an additive component, for example detergent metal, molybdenum or boron content or total metal content of the lubricating oil composition (i.e. the sum of all individual metal contents), is measured by ASTM D5185;

"TBN" in relation to an additive component or of a lubricating oil composition of the present invention, means total base number (mg KOH/g) as measured by ASTM D2896;

"KV₁₀₀" means kinematic viscosity at 100°C as measured by ASTM D445;

"phosphorus content" is measured by ASTM D5185;

"sulfur content" is measured by ASTM D2622; and,

"sulfated ash content" is measured by ASTM D874.

[0011] All percentages reported are mass % on an active ingredient basis, i.e. without regard to carrier or diluent oil, unless otherwise stated.

[0012] Also, it will be understood that various components used, essential as well as optimal and customary, may react under conditions of formulation, storage or use and that the invention also provides the product obtainable or obtained as a result of any such reaction.

[0013] Further, it is understood that any upper and lower quantity, range and ratio limits set forth herein may be independently combined.

[0014] Also, it will be understood that the preferred features of each aspect of the present invention are regarded as preferred features of every other aspect of the present invention.

BRIEF DESCRIPTION OF THE FIGURES

[0015]

Fig. 1 represents graphically, the results shown in Table 2.

Fig. 2 represents graphically, the results shown in Table 3.

Figs. 3 - 6 represent graphically, the results of Example 2.

Fig. 7 represents graphically, the results shown in Table 5.

Fig. 8 represents graphically, the results shown in Table 6.

DETAILED DESCRIPTION OF THE INVENTION

OIL OF LUBRICATING VISCOSITY

[0016] The oil of lubricating viscosity (sometimes referred to as "base stock" or "base oil") is the primary liquid constituent of a lubricant, into which additives and possibly other oils are blended, for example to produce a final lubricant (or lubricant composition). A base oil is useful for making concentrates as well as for making lubricating oil compositions therefrom, and may be selected from natural (vegetable, animal or mineral) and synthetic lubricating oils and mixtures thereof.

[0017] The base stock groups are defined in the American Petroleum Institute (API) publication "Engine Oil Licensing and Certification System", Industry Services Department, Fourteenth Edition, December 1996, Addendum 1, December 1998. Typically, the base stock will have a viscosity preferably of 3-12, more preferably 4-10, most preferably 4.5-8, mm²/s (cSt) at 100°C.

[0018] Definitions for the base stocks and base oils in this invention are the same as those found in the American Petroleum Institute (API) publication "Engine Oil Licensing and Certification System", Industry Services Department, Fourteenth Edition, December 1996, Addendum 1, December 1998. Said publication categorizes base stocks as follows:

a) Group I base stocks contain less than 90 percent saturates and/or greater than 0.03 percent sulphur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1.

b) Group II base stocks contain greater than or equal to 90 percent saturates and less than or equal to 0.03 percent sulphur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1.

c) Group III base stocks contain greater than or equal to 90 percent saturates and less than or equal to 0.03 percent sulphur and have a viscosity index greater than or equal to 120 using the test methods specified in Table E-1.

d) Group IV base stocks are polyalphaolefins (PAO).

e) Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

Table E-1: Analytical Methods for Base Stock

Property	Test Method
Saturates	ASTM D 2007
Viscosity Index	ASTM D 2270
Sulphur	ASTM D 2622

(continued)

Property	Test Method
	ASTM D 4294
	ASTM D 4927
	ASTM D 3120

[0019] Other oils of lubricating viscosity which may be included in the lubricating oil composition are detailed as follows.

[0020] Natural oils include animal and vegetable oils (e.g. castor and lard oil), liquid petroleum oils and hydrotreated, solvent-treated mineral lubricating oils of the paraffinic, naphthenic and mixed paraffinic-naphthenic types. Oils of lubricating viscosity derived from coal or shale are also useful base oils.

[0021] Synthetic lubricating oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g. polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes)); alkylbenzenes (e.g. dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)benzenes); polyphenols (e.g. biphenyls, terphenyls, alkylated polyphenols); and alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogues and homologues thereof.

[0022] Another suitable class of synthetic lubricating oils comprises the esters of dicarboxylic acids (e.g. phthalic acid, succinic acid, alkyl succinic acids and alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkylmalonic acids, alkenyl malonic acids) with a variety of alcohols (e.g. butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol). Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid.

[0023] Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols, and polyol ethers such as neopentyl glycol, trimethylolpropane, pentaerythritol, dipentaerythritol and tripentaerythritol.

[0024] Unrefined, refined and re-refined oils can be used in the compositions of the present invention. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. For example, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from distillation or ester oil obtained directly from an esterification process and used without further treatment would be unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques, such as distillation, solvent extraction, acid or base extraction, filtration and percolation are known to those skilled in the art. Re-refined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such re-refined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques for approval of spent additive and oil breakdown products.

[0025] Other examples of base oil are gas-to-liquid ("GTL") base oils, i.e. the base oil may be an oil derived from Fischer-Tropsch synthesised hydrocarbons made from synthesis gas containing H₂ and CO using a Fischer-Tropsch catalyst. These hydrocarbons typically require further processing in order to be useful as a base oil. For example, they may, by methods known in the art, be hydroisomerized; hydrocracked and hydroisomerized; dewaxed; or hydroisomerized and dewaxed.

[0026] Whilst the composition of the base oil will depend upon the particular application of the lubricating oil composition and the oil formulator will choose the base oil to achieve desired performance characteristics at reasonable cost, the oil of a lubricating viscosity of the lubricating oil composition according to all aspects of the present invention typically comprises Group II or Group III base oil in the majority. The oil of a lubricating viscosity of the lubricating oil composition according to all aspects of the present invention may comprise at least 50 mass% Group III and/or Group II base oil, such as at least 70 mass% or even at least 80 mass% Group III and/or Group II base oil, based on the mass of the oil of lubricating viscosity in the lubricating oil composition. The oil of lubricating viscosity may comprise 100 mass% of Group III and/or Group II base oil, based on the mass of the oil of lubricating viscosity in the lubricating oil composition.

[0027] Preferably, the volatility of the oil of lubricating viscosity or oil blend, as measured by the NOACK test (ASTM D5800), is less than or equal to 20 %, preferably less than or equal to 16 %, preferably less than or equal to 12 %, more preferably less than or equal to 10 %. Preferably, the viscosity index (VI) of the oil of lubricating viscosity is at least 95, preferably at least 110, more preferably up to 120, even more preferably at least 120, even more preferably at least 125, most preferably from about 130 to 140.

[0028] Preferably, the oil of lubricating viscosity is present in an amount of greater than 55 mass %, more preferably greater than 60 mass %, even more preferably greater than 70 mass %, based on the total mass of the lubricating oil

composition. Preferably, the oil of lubricating viscosity is present in an amount of less than 98 mass %, more preferably less than 95 mass %, even more preferably less than 90 mass %, based on the total mass of the lubricating oil composition.

[0029] The lubricating oil composition of each aspect of the present invention may be a multigrade oil identified by the viscometric descriptor SAE 20WX, SAE 15WX, SAE 10WX, SAE 5WX or SAE 0WX, 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 10WX, SAE 5WX or SAE 0WX, preferably in the form of a SAE 10WX or SAE 5WX viscosity grade, wherein X represents any one of 20, 30, 40 and 50. Preferably X is 30 or 40.

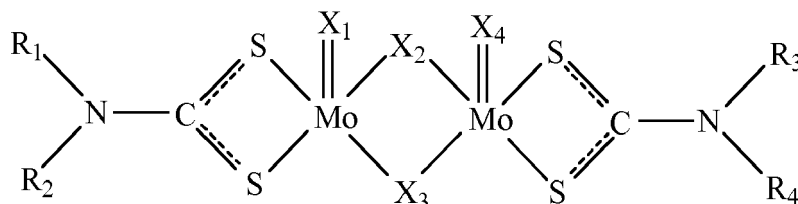
OIL-SOLUBLE MOLYBDENUM COMPOUND (A)

[0030] For the lubricating oil compositions of all aspects of the present invention, any suitable oil-soluble or oil-dispersible molybdenum compound having friction modifying properties in lubricating oil compositions may be employed.

[0031] Preferably, the oil-soluble or oil-dispersible molybdenum compound is an oil-soluble or oil-dispersible organo-molybdenum compound. As examples of such organo-molybdenum compounds, there may be mentioned molybdenum dithiocarbamates, molybdenum dithiophosphates, molybdenum dithiophosphinates, molybdenum xanthates, molybdenum thioxanthates, molybdenum sulfides, and the like, and mixtures thereof. Particularly preferred are molybdenum dithiocarbamates, molybdenum dialkyldithiophosphates, molybdenum alkyl xanthates and molybdenum alkylthioxanthates. Especially preferred organo-molybdenum compounds are molybdenum dithiocarbamates. In an embodiment of the present invention the oil-soluble or oil-dispersible molybdenum compound consists of either a molybdenum dithiocarbamate or a molybdenum dithiophosphate or a mixture thereof, as the sole source of molybdenum atoms in the lubricating oil composition. In an alternative embodiment of the present invention the oil-soluble or oil-dispersible molybdenum compound consists of a molybdenum dithiocarbamate, as the sole source of molybdenum atoms in the lubricating oil composition.

[0032] The molybdenum compound may be mono-, di-, tri- or tetra-nuclear. Di-nuclear and tri-nuclear molybdenum compounds are preferred.

[0033] Suitable dinuclear or dimeric molybdenum dialkyldithiocarbamate are represented by the following formula:



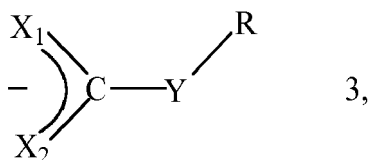
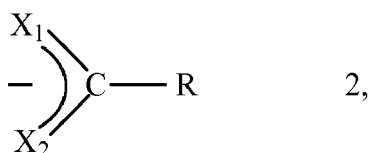
wherein R_1 through R_4 independently denote a straight chain, branched chain or aromatic hydrocarbyl group having 1 to 24 carbon atoms; and X_1 through X_4 independently denote an oxygen atom or a sulfur atom. The four hydrocarbyl groups, R_1 through R_4 , may be identical or different from one another.

[0034] Other molybdenum compounds useful in the compositions of this invention are organo-molybdenum compounds of the formulae $\text{Mo}(\text{ROCS}_2)_4$ and $\text{Mo}(\text{RSCS}_2)_4$, wherein R is an organo group selected from the group consisting of alkyl, aryl, aralkyl and alkoxyalkyl, generally of from 1 to 30 carbon atoms, and preferably 2 to 12 carbon atoms and most preferably alkyl of 2 to 12 carbon atoms. Especially preferred are the dialkyldithiocarbamates of molybdenum.

[0035] Suitable tri-nuclear organo-molybdenum compounds include those of the formula $\text{Mo}_3\text{S}_k\text{L}_n\text{Q}_z$ and mixtures thereof wherein L are independently selected ligands having organo groups with a sufficient number of carbon atoms to render the compound soluble or dispersible in the oil, n is from 1 to 4, k varies from 4 through 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.

[0036] The ligands are independently selected from the group of:

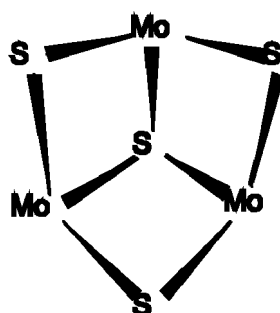




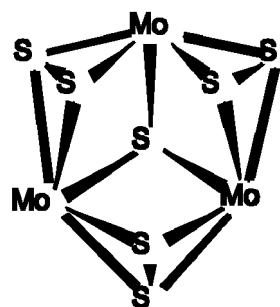
and mixtures thereof, wherein X, X_1 , X_2 , and Y are independently selected from the group of oxygen and sulfur, and wherein R_1 , R_2 , and R are independently selected from hydrogen and organo groups that may be the same or different. Preferably, the organo groups are hydrocarbyl groups such as alkyl (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.

[0037] Importantly, the organo groups of the ligands have a sufficient number of carbon atoms to render the compound soluble or dispersible in the oil. For example, the number of carbon atoms in each group will generally range between about 1 to about 100, preferably from about 1 to about 30, and more preferably between about 4 to about 20. Preferred ligands include dialkyldithiophosphate, alkylxanthate, and dialkyldithiocarbamate, and of these dialkyldithiocarbamate is more preferred. Organic ligands containing two or more of the above functionalities are also capable of serving as ligands and binding to one or more of the cores. 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.

[0038] Compounds having the formula $Mo_3S_kL_nQ_z$ have cationic cores surrounded by anionic ligands and are represented by structures such as



and



and have net charges of +4. Consequently, in order to solubilize these cores the total charge among all the ligands must be -4. Four mono-anionic ligands are preferred. Without wishing to be bound by any theory, it is believed that two or more tri-nuclear cores may be bound or interconnected by means of one or more ligands and the ligands may be multidentate. This includes the case of a multidentate ligand having multiple connections to a single core. It is believed that oxygen and/or selenium may be substituted for sulfur in the core(s).

[0039] Oil-soluble or oil-dispersible tri-nuclear 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 tetralkylthiuram disulfide. Other oil-soluble or dispersible tri-nuclear molybdenum compounds can be formed during a reaction in the appropriate solvent(s) of a molybdenum source such as of $(\text{NH}_4)_2\text{Mo}_3\text{S}_{13}\cdot n(\text{H}_2\text{O})$, a ligand source such as tetralkylthiuram disulfide, dialkyldithiocarbamate, or dialkyldithiophosphate, and a sulfur abstracting agent such as cyanide ions, sulfite ions, or substituted phosphines. Alternatively, a tri-nuclear 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 or dispersible trinuclear molybdenum compound. The appropriate liquid/solvent may be, for example, aqueous or organic.

[0040] A compound's oil solubility or dispersibility may be influenced by the number of carbon atoms in the ligand's organo groups. Preferably, at least 21 total carbon atoms should be present among all the ligands' organo groups. Preferably, the ligand source chosen has a sufficient number of carbon atoms in its organo groups to render the compound soluble or dispersible in the lubricating composition.

[0041] The amount of oil-soluble molybdenum compound will depend upon the particular performance requirements of the lubricating oil composition. Suitably, the lubricating oil composition of all aspects of the present invention contains the molybdenum compound in an amount providing the composition with at least 30ppm or at least 50ppm of molybdenum (ASTM D5185). The lubricating oil composition of all aspects of the present invention may contain the molybdenum compound in an amount providing the composition with up to 1000 ppm, or up to 500ppm or up to 200ppm, or up to 150 ppm of molybdenum (ASTM D5185).

ASHLESS ORGANIC FRICTION MODIFIER (B)

[0042] Ashless friction modifiers suitable for use in the lubricating oil composition of all aspects of the present invention include nitrogen-free organic friction modifiers and include esters formed by reacting carboxylic acids and anhydrides with alkanols. Other suitable friction modifiers include a polar terminal group (e.g. carboxyl or hydroxyl) covalently bonded to an oleophilic hydrocarbon chain. Esters of carboxylic acids and anhydrides with alkanols are described in US 4,702,850. Examples of other conventional organic friction modifiers 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. 1, pp. 3-26.

[0043] Preferred organic ashless nitrogen-free friction modifiers are esters or ester-based; a particularly preferred organic ashless nitrogen-free friction modifier is glycerol monooleate (GMO).

[0044] Other preferred ashless organic friction modifiers include alkenyl substituted anhydrides, such as octadecenyl succinic anhydride.

[0045] Ashless aminic or amine-based friction modifiers may also be used and include oil-soluble alkoxyated mono- and di-amines, which improve boundary layer lubrication. One common class of such metal free, nitrogen-containing friction modifier comprises ethoxylated alkyl amines. They may be 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. Another metal free, nitrogen-containing friction modifier is an ester formed as the reaction product of (i) a tertiary amine of the formula $\text{R}_1\text{R}_2\text{R}_3\text{N}$ wherein R_1 , R_2 and R_3 represent aliphatic hydrocarbyl, preferably alkyl, groups having 1 to 6 carbon atoms, at least one of R_1 , R_2 and R_3 having a hydroxyl group, with (ii) a saturated or unsaturated fatty acid having 10 to 30 carbon atoms. Preferably, at least one of R_1 , R_2 and R_3 is an alkyl group. Preferably, the tertiary amine will have at least one hydroxyalkyl group having 2 to 4 carbon atoms. The ester may be a mono-, di- or tri-ester or a mixture thereof, depending on how many hydroxyl groups are available for esterification with the acyl group of the fatty acid. The ashless organic friction modifier of all aspects of the present invention may comprise a mixture of esters formed as the reaction product of (i) a tertiary hydroxy amine of the formula $\text{R}_1\text{R}_2\text{R}_3\text{N}$ wherein R_1 , R_2 and R_3 may be a C_2 - C_4 hydroxy alkyl group with (ii) a saturated or unsaturated fatty acid having 10 to 30 carbon atoms, with a mixture of esters so formed comprising at least 30-60 mass%, preferably 45-55 mass% diester, such as 50 mass% diester, 10-40 mass%, preferably 20-30 mass% monoester, e.g. 25 mass% monoester, and 10-40 mass%, preferably 20-30 mass% triester, such as 25 mass% triester. Suitably, the ester is a mono-, di- or tri-carboxylic acid ester of triethanolamine and mixtures thereof.

[0046] Typically, the total amount of ashless organic friction modifier (B) in the lubricating oil composition of all aspects of the present invention does not exceed 5 mass %, based on the total mass of the lubricating oil composition and preferably does not exceed 2 mass % and more preferably does not exceed 0.5 mass %.

ASHLESS DISPERSANT (C)

[0047] The lubricating oil of all aspects of the present invention may also comprise a dispersant additive.

[0048] A dispersant is an additive whose primary function is to hold solid and liquid contaminations in suspension,

thereby passivating them and reducing engine deposits at the same time as reducing sludge depositions. For example, a dispersant maintains in suspension oil-insoluble substances that result from oxidation during use of the lubricant, thus preventing sludge flocculation and precipitation or deposition on metal parts of the engine.

[0049] Dispersants are usually "ashless", as mentioned above, being non-metallic organic materials that form substantially no ash on combustion, in contrast to metal-containing, and hence ash-forming materials. They comprise a long hydrocarbon chain with a polar head, the polarity being derived from inclusion of e.g. an O, P, or N atom. The hydrocarbon is an oleophilic group that confers oil-solubility, having, for example 40 to 500 carbon atoms. Thus, ashless dispersants may comprise an oil-soluble polymeric backbone.

[0050] The ashless dispersant suitable for all aspects of the present invention is preferably an ashless, nitrogen-containing dispersant.

[0051] Suitable ashless dispersant may be made from polyalkenes that have been functionalised exclusively by the thermal "ene" reaction, a known reaction. Such polyalkenes are mixtures having predominantly terminal vinylidene groups, such as at least 65, e.g. 70, more preferably at least 85, %. As an example, there may be mentioned a polyalkene known as highly reactive polyisobutene (HR-PIB), which is commercially available under the tradename Glissopal™ (ex BASF). US-A-4 152 499 describes the preparations of such polymers.

[0052] Alternatively, the ashless dispersant may be made from polyalkenes that have been functionalised by the so-called chlorination method, which results in a product where minor percentage of its polymer chains (e.g. less than 20%) have terminal vinylidene groups.

[0053] Preferred monounsaturated reactants that may be used to functionalize the polyalkene comprise mono- and dicarboxylic acid material, i.e., acid, anhydride, or acid ester material, including (i) monounsaturated C₄ to C₁₀ dicarboxylic acid wherein (a) the carboxyl groups are vicinyl, (i.e., located on adjacent carbon atoms) and (b) at least one, preferably both, of said adjacent carbon atoms are part of said mono unsaturation; (ii) derivatives of (i) such as anhydrides or C₁ to C₅ alcohol derived mono- or diesters of (i); (iii) monounsaturated C₃ to C₁₀ monocarboxylic acid wherein the carbon-carbon double bond is conjugated with the carboxy group, i.e., of the structure -C=C-CO-; and (iv) derivatives of (iii) such as C₁ to C₅ alcohol derived mono- or diesters of (iii). Mixtures of monounsaturated carboxylic materials (i) - (iv) also may be used. Upon reaction with the polyalkene, the monounsaturated of the monounsaturated carboxylic reactant becomes saturated. Thus, for example, maleic anhydride becomes polyalkene-substituted succinic anhydride, and acrylic acid becomes polyalkene-substituted propionic acid. Exemplary of such monounsaturated carboxylic reactants are fumaric acid, itaconic acid, maleic acid, maleic anhydride, acrylic acid, methacrylic acid, crotonic acid, cinnamic acid, and lower alkyl (e.g., C₁ to C₄ alkyl) acid esters of the foregoing, e.g., methyl maleate, ethyl fumarate, and methyl fumarate.

[0054] To provide the required functionality, monounsaturated carboxylic reactants, preferably maleic anhydride, typically will be used in an amount ranging from equimolar to 100, preferably 5 to 50, wt. % excess, based on the moles of polyalkene. Unreacted excess monounsaturated carboxylic reactant can be removed from the final dispersant product by, for example, stripping, usually under vacuum, if required.

[0055] The functionalised oil-soluble polyalkene is then derivatized with a nucleophilic reactant, such as an amine, amino-alcohol, alcohol, or mixture thereof, to form a corresponding derivative containing the dispersant. Useful amine compounds for derivatizing functionalized polymers comprise at least one amine and can comprise one or more additional amine or other reactive or polar groups. These amines may be hydrocarbyl amines or may be predominantly hydrocarbyl amines in which the hydrocarbyl group includes other groups, e.g., hydroxy groups, alkoxy groups, amide groups, nitriles and imidazoline groups. Particularly useful amine compounds include mono- and polyamines, e.g., polyalkene and polyoxyalkylene polyamines of 2 to 60, such as 2 to 40 (e.g., 3 to 20), total carbon atoms having 1 to 12, such as 3 to 12, preferably 3 to 9, most preferably 6 to 7, nitrogen atoms per molecule. Mixtures of amine compounds may advantageously be used. Preferred amines are aliphatic saturated amines, including, for example, 1,2-diaminoethane; 1,3-diaminopropane; 1,4-diaminobutane; 1,6-diaminohexane; polyethylene amines such as diethylene triamine; triethylene tetramine; tetraethylene pentamine; and polypropyleneamines such as 1,2-propylene diamine; and di-(1,2-propylene)tri-amine. Such polyamine mixtures, known as PAM, are commercially available. Particularly preferred polyamine mixtures are mixtures derived by distilling the light ends from PAM products. The resulting mixtures, known as "heavy" PAM, or HPAM, are also commercially available. The properties and attributes of both PAM and/or HPAM are described, for example, in U.S. Patent Nos. 4,938,881; 4,927,551; 5,230,714; 5,241,003; 5,565,128; 5,756,431; 5,792,730; and 5,854,186.

[0056] Other useful amine compounds include: alicyclic diamines such as 1,4-di(aminomethyl) cyclohexane and heterocyclic nitrogen compounds such as imidazolines. Another useful class of amines is the polyamido and related amidoamines as disclosed in U.S. Patent Nos. 4,857,217; 4,956,107; 4,963,275; and 5,229,022. Also usable is tris(hydroxymethyl)amino methane (TAM) as described in U.S. Patent Nos. 4,102,798; 4,113,639; 4,116,876; and UK 989,409. Dendrimers, star-like amines, and comb-structured amines may also be used. Similarly, condensed amines, as described in U.S. Patent No. 5,053,152 may be used. The functionalized polymer is reacted with the amine compound using conventional techniques as described, for example, in U.S. Patent Nos. 4,234,435 and 5,229,022, as well as in EP-A-208,560.

[0057] A dispersant of the present invention preferably comprises at least one dispersant that is derived from polyalkenyl-substituted mono- or dicarboxylic acid, anhydride or ester, which has from greater than 1.3 to 1.7, preferably from greater than 1.3 to 1.6, most preferably from greater than 1.3 to 1.5, functional groups (mono- or dicarboxylic acid producing moieties) per polyalkenyl moiety (a medium functionality dispersant). Functionality (F) can be determined according to the following formula:

$$F = (\text{SAP} \times M_n) / ((112,200 \times \text{A.I.}) - (\text{SAP} \times \text{MW})) \quad (1)$$

wherein SAP is the saponification number (i.e., the number of milligrams of KOH consumed in the complete neutralization of the acid groups in one gram of the succinic-containing reaction product, as determined according to ASTM D94); M_n is the number average molecular weight of the starting olefin polymer; A.I. is the percent active ingredient of the succinic-containing reaction product (the remainder being unreacted olefin polymer, succinic anhydride and diluent); and MW is the molecular weight of the mono- or dicarboxylic acid producing moieties (e.g., 98 for maleic anhydride).

[0058] Generally, each mono- or dicarboxylic acid-producing moiety will react with a nucleophilic group (amine, alcohol, amide or ester polar moieties) and the number of functional groups in the polyalkenyl-substituted carboxylic acylating agent will determine the number of nucleophilic groups in the finished dispersant.

[0059] The polyalkenyl moiety of the dispersant of the present invention may have a number average molecular weight of at least 900, suitably at least 1500, preferably between 1800 and 3000, such as between 2000 and 2800, more preferably from about 2100 to 2500, and most preferably from about 2200 to about 2400. The molecular weight of a dispersant is generally expressed in terms of the molecular weight of the polyalkenyl moiety; this is because the precise molecular weight range of the dispersant depends on numerous parameters including the type of polymer used to derive the dispersant, the number of functional groups, and the type of nucleophilic group employed.

[0060] Polymer molecular weight, specifically $\overline{M}_n$, can be determined by various known techniques. One convenient method is gel permeation chromatography (GPC), which additionally provides molecular weight distribution information (see W. W. Yau, J. J. Kirkland and D. D. Bly, "Modern Size Exclusion Liquid Chromatography", John Wiley and Sons, New York, 1979). Another useful method for determining molecular weight, particularly for lower molecular weight polymers, is vapor pressure osmometry (see, e.g., ASTM D3592).

[0061] The polyalkenyl moiety in a dispersant of the present invention preferably has a narrow molecular weight distribution (MWD), also referred to as polydispersity, as determined by the ratio of weight average molecular weight (M_w) to number average molecular weight (M_n). Polymers having a M_w/M_n of less than 2.2, preferably less than 2.0, are most desirable. Suitable polymers have a polydispersity of from about 1.5 to 2.1, preferably from about 1.6 to about 1.8.

[0062] Suitable polyalkenes employed in the formation of the dispersants of the present invention include homopolymers, interpolymers or lower molecular weight hydrocarbons. One family of such polymers comprise polymers of ethylene and/or at least one C_3 to C_{28} alpha-olefin having the formula $H_2C=CHR^1$ wherein R^1 is a straight or branched chain alkyl radical comprising 1 to 26 carbon atoms and wherein the polymer contains carbon-to-carbon unsaturation, and a high degree of terminal ethenylidene unsaturation. Preferably, such polymers comprise interpolymers of ethylene and at least one alpha-olefin of the above formula, wherein R^1 is alkyl of from 1 to 18 carbon atoms, and more preferably is alkyl of from 1 to 8 carbon atoms, and more preferably still of from 1 to 2 carbon atoms.

[0063] Another useful class of polymers is polymers prepared by cationic polymerization of monomers such as isobutene and styrene. Common polymers from this class include polyisobutenes obtained by polymerization of a C_4 refinery stream having a butene content of 35 to 75% by wt., and an isobutene content of 30 to 60% by wt., by the thermal "ene" reaction. A preferred source of monomer for making poly-n-butenes is petroleum feedstreams such as Raffinate II. These feedstocks are disclosed in the art such as in U.S. Patent No. 4,952,739. A preferred embodiment utilizes polyisobutylene prepared from a pure isobutylene stream or a Raffinate I stream to prepare reactive isobutylene polymers with terminal vinylidene olefins as described above.

[0064] The dispersant(s) of the invention are preferably mono- or bis-succinimides.

[0065] The dispersant(s) of the present invention can be borated by conventional means, as generally taught in U.S. Patent Nos. 3,087,936, 3,254,025 and 5,430,105. Boration of the dispersant is readily accomplished by treating an acyl nitrogen-containing dispersant with a boron compound such as boron oxide, boron halide boron acids, and esters of boron acids, in an amount sufficient to provide from 0.1 to 20 atomic proportions of boron for each mole of acylated nitrogen composition.

[0066] The boron, which appears in the product as dehydrated boric acid polymers (primarily $(HBO_2)_3$), is believed to attach, for example, to dispersant imides and diimides as amine salts, e.g., the metaborate salt of the diimide. Boration can be carried out by adding a sufficient quantity of a boron compound, preferably boric acid, usually as a slurry, to the acyl nitrogen compound and heating with stirring at from 135°C to 190, e.g., 140 to 170, °C, for from 1 to 5 hours, followed by nitrogen stripping. Alternatively, the boron treatment can be conducted by adding boric acid to a hot reaction mixture

of the dicarboxylic acid material and amine, while removing water. Other post-reaction processes known in the art can also be applied.

[0067] Typically, the lubricating oil composition may contain from 1 to 20, such as 3 to 15, preferably 3 to 12, mass % dispersant.

[0068] The ashless dispersant (D) of all aspects of the present invention may comprise a mixture of ashless dispersant compounds. In a preferred embodiment of all aspects of the present invention, the lubricating oil composition comprises an ashless dispersant made by the thermal "ene" process. If the lubricating oil composition comprises a mixture of ashless dispersant additives, an ashless dispersant made by the thermal "ene" process preferably provides the majority of the ashless dispersant. For example, the ashless dispersant (D) may comprise at least 50 mass%, or at least 70% or at least 75% ashless dispersant made by the thermal process. In an embodiment of all aspects of the present invention the ashless dispersant (D) comprises only dispersant made by the thermal process.

[0069] The amount of nitrogen in a lubricating oil composition according to the present invention will depend upon the particular application of the oil. Typically, a lubricating oil composition according to the present invention contains at least 0.02, such as at least 0.03 or 0.04 mass % nitrogen, based on the total mass of the composition and as measured according to ASTM method D5291. Suitably, the lubricating oil composition will contain no more than 0.20, such as no more than 0.15 or no more than 0.12 mass % nitrogen based upon the total mass of the composition and as measured according to ASTM D5291.

METAL-CONTAINING DETERGENT (E)

[0070] Suitably the lubricating oil composition of all aspects of the present invention further comprises at least one metal-containing detergent additive.

[0071] Metal-containing detergents function both as detergents to reduce or remove deposits and as acid neutralizers or rust inhibitors, thereby reducing wear and corrosion and extending engine life. Detergents generally comprise a polar head with a long hydrophobic tail, with the polar head comprising a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal in which case they are usually described as normal or neutral salts, and would typically have a total base number or TBN (as can be measured by ASTM D2896) of from 0 to 80 mg KOH/g. A large amount of a metal base may be incorporated by reacting excess metal compound (e.g., an oxide or hydroxide) with an acidic gas (e.g., carbon dioxide). The resulting overbased detergent comprises neutralized detergent as the outer layer of a metal base (e.g. carbonate) micelle. Such overbased detergents may have a TBN of 150 mg KOH/g or greater, and typically will have a TBN of from 250 to 450 mg KOH/g or more. In the presence of the compounds of Formula I, the amount of overbased detergent can be reduced, or detergents having reduced levels of overbasing (e.g., detergents having a TBN of 100 to 200 mg KOH/g), or neutral detergents can be employed, resulting in a corresponding reduction in the SASH content of the lubricating oil composition without a reduction in the performance thereof.

[0072] Detergents that may be used include oil-soluble neutral and overbased sulfonates, phenates, sulfurized phenates, thiophosphonates, salicylates, and naphthenates and other oil-soluble carboxylates of a metal, particularly the alkali or alkaline earth metals, e.g., sodium, potassium, lithium, calcium, and magnesium. The most commonly used metals are calcium and magnesium, which may both be present in detergents used in a lubricating oil composition according to any aspect of the present invention. Combinations of detergents, whether overbased or neutral or both, may be used.

[0073] Sulfonates may be prepared from sulfonic acids which are typically obtained by the sulfonation of alkyl substituted aromatic hydrocarbons such as those obtained from the fractionation of petroleum or by the alkylation of aromatic hydrocarbons. Examples included those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl or their halogen derivatives such as chlorobenzene, chlorotoluene and chloronaphthalene. The alkylation may be carried out in the presence of a catalyst with alkylating agents having from about 3 to more than 70 carbon atoms. The alkaryl sulfonates usually contain from about 9 to about 80 or more carbon atoms, preferably from about 16 to about 60 carbon atoms per alkyl substituted aromatic moiety. The oil soluble sulfonates or alkaryl sulfonic acids may be neutralized with oxides, hydroxides, alkoxides, carbonates, carboxylate, sulfides, hydrosulfides, nitrates, borates and ethers of the metal. The amount of metal compound is chosen having regard to the desired TBN of the final product but typically ranges from about 100 to 220 mass % (preferably at least 125 mass %) of that stoichiometrically required.

[0074] Metal salts of phenols and sulfurized phenols are prepared by reaction with an appropriate metal compound such as an oxide or hydroxide and neutral or overbased products may be obtained by methods well known in the art. Sulfurized phenols may be prepared by reacting a phenol with sulfur or a sulfur containing compound such as hydrogen sulfide, sulfur monohalide or sulfur dihalide, to form products which are generally mixtures of compounds in which 2 or more phenols are bridged by sulfur containing bridges.

[0075] Carboxylate detergents, e.g., salicylates, can be prepared by reacting an aromatic carboxylic acid with an appropriate metal compound such as an oxide or hydroxide and neutral or overbased products may be obtained by methods well known in the art. 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. 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.

[0076] Preferred substituents in oil-soluble salicylic acids are alkyl substituents. In alkyl - substituted 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.

[0077] The metal-containing detergent (E) may comprise one or more metal detergents that are neutral or overbased alkali or alkaline earth metal salicylates. Highly preferred salicylate detergents include alkaline earth metal salicylates, particularly magnesium and calcium, especially, calcium salicylates. The metal salicylate may be the sole metal-containing detergent present in the lubricating oil composition of all aspects of the present invention. Alternatively, other metal-containing detergents, such as metal sulfonates or phenates, may be present in the lubricating composition. Preferably, the salicylate detergent provides the majority of the detergent additive in the lubricating oil composition.

[0078] The total amount of metal-containing detergent additive present in the lubricating oil composition according to any aspect of the present invention is suitably in the range of 0.1-10 mass%, preferably from 0.5 to 5 mass% on an active matter basis.

CO-ADDITIVES

[0079] Lubricating oil compositions according to each aspect of the invention may additionally comprise one or more co-additives, which are different from additive components (B), (C), (D) and (E). Suitable co-additives and their common treat rates are discussed below. All the values listed are stated as mass percent active ingredient in a fully formulated lubricant.

Additive	Mass %	Mass %
	(Broad)	(Preferred)
Corrosion Inhibitor	0 - 5	0 - 1.5
Metal Dihydrocarbyl Dithiophosphate	0 - 10	0 - 4
Anti-Oxidants	0 - 5	0.01 - 3
Pour Point Depressant	0.01 - 5	0.01 - 1.5
Anti-Foaming Agent	0 - 5	0.001 - 0.15
Viscosity Modifier (1)	0 - 10	0.01 - 4
Mineral or Synthetic Base Oil	Balance	Balance
(1) Viscosity modifiers are used only in multi-graded oils.		

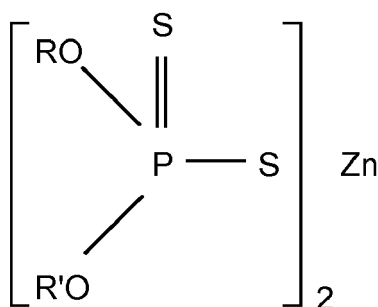
[0080] The final lubricating oil composition, typically made by blending the or each additive into the base oil, may contain from 5 to 25, preferably 5 to 18, typically 7 to 15, mass % of the additives; the remainder being oil of lubricating viscosity.

[0081] The above mentioned co-additives are discussed in further detail as follows; as is known in the art, some additives can provide a multiplicity of effects, for example, a single additive may act as a dispersant and as an oxidation inhibitor.

[0082] Anti-wear agents reduce friction and excessive wear and are usually based on compounds containing sulfur or phosphorous or both, for example that are capable of depositing polysulfide films on the surfaces involved. Noteworthy are dihydrocarbyl dithiophosphate metal salts wherein the metal may be an alkali or alkaline earth metal, or aluminium, lead, tin, molybdenum, manganese, nickel, copper, or preferably, zinc.

[0083] Dihydrocarbyl dithiophosphate metal salts may be prepared in accordance with known techniques by first forming a dihydrocarbyl dithiophosphoric acid (DDPA), usually by reaction of one or more alcohols or a phenol with P_2S_5 and then neutralizing the formed DDPA with a metal compound. For example, a dithiophosphoric acid may be made by reacting mixtures of primary and secondary alcohols. Alternatively, multiple dithiophosphoric acids can be prepared where the hydrocarbyl groups on one are entirely secondary in character and the hydrocarbyl groups on the others are entirely primary in character. To make the metal salt, any basic or neutral metal compound could be used but the oxides, hydroxides and carbonates are most generally employed. Commercial additives frequently contain an excess of metal due to the use of an excess of the basic metal compound in the neutralization reaction.

[0084] The preferred zinc dihydrocarbyl dithiophosphates (ZDDP) are oil-soluble salts of dihydrocarbyl dithiophosphoric acids and may be represented by the following formula:



wherein R and R' may be the same or different hydrocarbonyl radicals containing from 1 to 18, preferably 2 to 12, carbon atoms and including radicals such as alkyl, alkenyl, aryl, arylalkyl, alkaryl and cycloaliphatic radicals. Particularly preferred as R and R' groups are alkyl groups of 2 to 8 carbon atoms. Thus, the radicals may, for example, be ethyl, n-propyl, i-propyl, n-butyl, i-butyl, sec-butyl, amyl, n-hexyl, i-hexyl, n-octyl, decyl, dodecyl, octadecyl, 2-ethylhexyl, phenyl, butyl-phenyl, cyclohexyl, methylcyclopentyl, propenyl, butenyl. In order to obtain oil solubility, the total number of carbon atoms (i.e. R and R') in the dithiophosphoric acid will generally be about 5 or greater. The zinc dihydrocarbonyl dithiophosphate can therefore comprise zinc dialkyl dithiophosphates.

[0085] The ZDDP is added to the lubricating oil compositions in amounts sufficient to provide at least 800 ppm such as at least 900ppm or at least 1000ppm by mass of phosphorous to the lubricating oil, based upon the total mass of the lubricating oil composition, and as measured in accordance with ASTM D5185.

[0086] The ZDDP is suitably added to the lubricating oil compositions in amounts sufficient to provide no more than 1200 ppm by mass of phosphorous to the lubricating oil, based upon the total mass of the lubricating oil composition, and as measured in accordance with ASTM D5185.

[0087] Viscosity modifiers (VM) function to impart high and low temperature operability to a lubricating oil. The VM used may have that sole function, or may be multifunctional. Multifunctional viscosity modifiers that also function as dispersants are also known. Suitable viscosity modifiers are polyisobutylene, copolymers of ethylene and propylene and higher alpha-olefins, polymethacrylates, polyalkylmethacrylates, methacrylate copolymers, copolymers of an unsaturated dicarboxylic acid and a vinyl compound, inter polymers of styrene and acrylic esters, and partially hydrogenated copolymers of styrene/ isoprene, styrene/butadiene, and isoprene/butadiene, as well as the partially hydrogenated homopolymers of butadiene and isoprene and isoprene/divinylbenzene. Preferred viscosity modifiers for all aspects of the present invention are copolymers of an unsaturated dicarboxylic acid and a vinyl compound, inter polymers of styrene and acrylic esters, and, most preferably, partially hydrogenated copolymers of styrene/ isoprene, styrene/butadiene, and isoprene/butadiene, as well as the partially hydrogenated homopolymers of butadiene and isoprene and isoprene/divinylbenzene. The preferred partially hydrogenated copolymers of styrene/ isoprene, styrene/butadiene, and isoprene/butadiene, may be random copolymers but are preferably block copolymers. The preferred, partially hydrogenated copolymers of styrene/isoprene, styrene/butadiene, and isoprene/butadiene, and partially hydrogenated homopolymers of butadiene and isoprene and isoprene/divinylbenzene viscosity modifiers may be linear polymers or star (radial) polymers.

[0088] Linear block copolymers useful in the practice of the present invention may be represented by the following general formula:



wherein:

A is a polymeric block comprising predominantly monoalkenyl aromatic hydrocarbon monomer units;

B is a polymeric block comprising predominantly conjugated diolefin monomer units;

x and z are, independently, a number equal to 0 or 1; and

y is a whole number ranging from 1 to about 15.

[0089] Useful tapered linear block copolymers may be represented by the following general formula:



wherein:

A is a polymeric block comprising predominantly monoalkenyl aromatic hydrocarbon monomer units;

B is a polymeric block comprising predominantly conjugated diolefin monomer units; and

A/B is a tapered segment containing both monoalkenyl aromatic hydrocarbon and conjugated diolefin units.

[0090] Star or radial homopolymers or random copolymers of diene(s) (e.g., isoprene and/or butadiene) may be represented, generally, by the following general formula:



wherein:

B and C are as previously defined; and

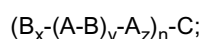
n is a number from 3 to 30;

C is the core of the radial polymer formed with a polyfunctional coupling agent;

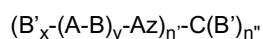
B' is a polymeric block comprising predominantly conjugated diolefin units, which B' may be the same or different from B; and

n' and n" are integers representing the number of each type of arm and the sum of n' and n" will be a number from 3 to 30.

[0091] Star or radial block copolymers may be represented, generally, by the following general formula:



and



wherein:

A, B, x, y and z are as previously defined;

n is a number from 3 to 30;

C is the core of the radial polymer formed with a polyfunctional coupling agent;

B' is a polymeric block comprising predominantly conjugated diolefin units, which B' may be the same or different from B; and

n' and n" are integers representing the number of each type of arm and the sum of n' and n" will be a number from 3 to 30.

[0092] As used herein in connection with polymer block composition, the term "predominantly" means that the specified monomer or monomer type which is the principle component in that polymer block is present in an amount of at least 85% by weight of the block.

[0093] Suitably, the lubricating oil composition according to all aspects of the present invention comprises one or more star polymer viscosity modifier. The lubricating oil composition according to all aspects of the present invention may comprise a mixture of linear and star polymer viscosity modifiers. In a preferred embodiment, the lubricating oil composition according to all aspects of the present invention comprises only star polymer viscosity modifier(s).

[0094] Oil-soluble viscosity modifying polymers generally have weight average molecular weights of from 10,000 to 1,000,000, preferably 20,000 to 500,000, which may be determined by gel permeation chromatography or by light scattering.

[0095] Anti-oxidants, sometimes referred to as oxidation inhibitors, increase the resistance of the composition to oxidation and may work by combining with and modifying peroxides to render them harmless, by decomposing peroxides, or by rendering oxidation catalysts inert. Oxidative deterioration can be evidenced by sludge in the lubricant, varnish-like deposits on the metal surfaces, and by viscosity growth.

[0096] Examples of suitable antioxidants are selected from copper-containing antioxidants, sulfur-containing antioxidants, aromatic amine-containing antioxidants, hindered phenolic antioxidants and dithiophosphates derivative. Preferred anti-oxidants ashless antioxidants. Preferred ashless antioxidants are ashless aromatic amine-containing antioxidants, ashless hindered phenolic antioxidants and mixtures thereof. In a preferred embodiment, one or more antioxidant is present in a lubricating oil composition of all aspects of the present invention.

[0097] Rust inhibitors selected from the group consisting of nonionic polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, and anionic alkyl sulfonic acids may be used.

[0098] Copper and lead bearing corrosion inhibitors may be used in some embodiments of the invention, and when

these compounds are included in the lubricating composition, they are preferably present in an amount not exceeding 0.2 wt. % active ingredient. However, in a preferred embodiment of the present invention, no copper-containing additives are present in the lubricating oil composition. When present, suitable such compounds are the thiadiazole polysulfides containing from 5 to 50 carbon atoms, their derivatives and polymers thereof. Derivatives of 1, 3, 4 thiadiazoles such as those described in U.S. Patent Nos. 2,719,125; 2,719,126; and 3,087,932; are typical. Other similar materials are described in U.S. Patent Nos. 3,821,236; 3,904,537; 4,097,387; 4,107,059; 4,136,043; 4,188,299; and 4,193,882. Other additives are the thio and polythio sulfenamides of thiadiazoles such as those described in UK Patent Specification No. 1,560,830. Benzotriazoles derivatives also fall within this class of additives..

[0099] A small amount of a demulsifying component may be used. A preferred demulsifying component is described in EP 330522. It is obtained by reacting an alkylene oxide with an adduct obtained by reacting a bis-epoxide with a polyhydric alcohol. The demulsifier should be used at a level not exceeding 0.1 mass % active ingredient. A treat rate of 0.001 to 0.05 mass % active ingredient is convenient.

[0100] 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. Typical of those additives which improve the low temperature fluidity of the fluid are C₈ to C₁₈ dialkyl fumarate/vinyl acetate copolymers, polyalkylmethacrylates and the like.

[0101] Foam control can be provided by many compounds including an antifoamant of the polysiloxane type, for example, silicone oil or polydimethyl siloxane.

[0102] The individual additives may be incorporated into a base stock in any convenient way. Thus, each of the components can be added directly to the base stock or base oil blend by dispersing or dissolving it in the base stock or base oil blend at the desired level of concentration. Such blending may occur at ambient or elevated temperatures.

[0103] Preferably, all the additives except for the viscosity modifier and the pour point depressant are blended into a concentrate or additive package described herein as the additive package that is subsequently blended into base stock to make the finished lubricant. The concentrate will typically be formulated to contain the additive(s) in proper amounts to provide the desired concentration in the final formulation when the concentrate is combined with a predetermined amount of a base lubricant.

[0104] The concentrate is preferably made in accordance with the method described in US 4,938,880. That patent describes making a pre-mix of ashless dispersant and metal detergents that is pre-blended at a temperature of at least about 100°C. Thereafter, the pre-mix is cooled to at least 85°C and the additional components are added.

[0105] The final crankcase lubricating oil formulation may employ from 2 to 20, preferably 4 to 18, and most preferably 5 to 17, mass % of the concentrate or additive package with the remainder being base stock.

[0106] The lubricating oil composition of the present invention may have a sulphated ash content of less than or equal to 1.2, preferably less than or equal to 1.1, more preferably less than or equal to 1.0, mass % (ASTM D874) based on the total mass of the composition. The lubricating oil composition of the present invention suitably has a sulphated ash content of at least 0.4, preferably at least 0.5, such as at least 0.6 mass % (ASTM D874) based on the total mass of the composition. Suitably the sulphated ash content of the lubricating oil composition is in the range of 0.04-1.2 mass%, preferably in the range of 0.06 to 1.0 mass% (ASTM D874).

[0107] The amount of sulfur in the lubricating oil composition will depend upon the particular application of the lubricating oil composition. The lubricating oil composition may contain sulphur in an amount of up to 0.4, such as, up to 0.35 mass % sulphur (ASTM D2622) based on the total mass of the composition. Generally the lubricating oil composition will contain at least 0.1, or even at least 0.2 mass% sulphur (ASTM D2622) based on the total mass of the composition.

[0108] Suitably, the lubricating oil composition of all aspects and embodiments of the present invention may have a total base number (TBN), as measured in accordance with ASTM D2896, of 4 to 15, preferably 4 to 10 mg KOH/g.

EXAMPLES

[0109] The invention will now be described in the following examples which are not intended to limit the scope of the claims hereof.

[0110] A series of 10W-30 oils as set out in Table 1 were blended. These oils were subjected to a variety of testing, as set out in Examples 1 and 2 below. The test methods used are described here.

[0111] The High Frequency Reciprocating Rig (HFRR- supplied by PCS Instruments) to evaluate the boundary regime friction characteristics of the oils.

[0112] The rig was set up with a 6mm ball on a 10mm disc. The test protocol employed was as follows:

Test Duration (mins)	1 min hold and 5 min run at each temperature stage
Test Load (N)	4

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(continued)

Frequency (Hz)	40
Stroke Length (microns)	1,000
Temperature (°C)	40, 60, 80, 100, 120, 140 (low temperature stage) 160, 180, 200, 220 (high temperature stage)

[0113] The test has 6 stages in the low temperature runs and 4 stages in the high temperature runs. The average friction at each temperature stage is measured and the overall average friction across all stages.

[0114] The JASO T 903:2016 clutch friction test measures clutch friction based on the SAE #2 test rig. The test runs at 3600rpm and duration of 1000 cycles of engagement and disengagement of the friction test plates. The friction coefficient of the test oil is measured in the test cycles. The test generates three different friction indices namely the Static Friction Index (SFI), Dynamic Friction Index (DFI) and Stop Time Index (STI). These indices are calculated based on the friction coefficients of the test oil against two standard reference oils. These three indices will determine the classification of the JASO friction performance to MA2, MA1, MA or MB based on the limits specified in the JASO T 903:2016 specification. The limits for each classification are set out below:

	MB	MA	MA1	MA2
DFI	≥0.40 and <1.35	≥1.35 and <2.5	≥1.35 and <1.50	≥1.50 and <2.5
SFI	≥0.40 and <1.45	≥1.45 and <2.5	≥1.45 and <1.60	≥1.60 and <2.5
STI	≥0.40 and <1.40	≥1.40 and <2.5	≥1.40 and <1.60	≥1.60 and <2.5

[0115] The mini traction machine (MTM) supplied by PCS Instruments, is a computer controlled traction and wear measurement instrument which provides controlled traction mapping of fluids. It measures the friction coefficient between a rotating ball on a rotating disk at variable entrainment speed. Contact was formed between ¾ inch ball mounted on a pivoting shaft, which is automatically loaded against a rotating 46mm diameter disc horizontally mounted in the test fluid reservoir. Variation of the entrainment speed simulates variation in the thickness of the lubricating oil film between the surfaces. As the MTM does not incorporate reciprocating motion, it generally correlates with the mixed and hydrodynamic lubrication regimes that are typical in bearings, pump and piston rings. The test was run at four temperatures, 60°C, 80°C, 100°C and 145 °C.

[0116] The Schwingung Reibung Verschleiss "SRV", supplied by Optimol, is used to evaluate friction and wear properties of liquid lubricants across a broad range of applications. There are different specimens and configurations that can be used in SRV; in these examples the rig was set up with a 15x22mm cylinder on a 24x7.9mm disk. The test has 6 temperature stages and you can record the average friction at each temperature stage and the overall average friction across all stages. The test protocol employed was as follows:

Test Duration (mins)	1 min hold and 5 min run at each temperature stage
Test Load (N)	400
Frequency (Hz)	50
Stroke Length (microns)	3,000
Temperature (°C)	60, 80, 100, 120, 140, 160

[0117] The test oil forms a film in between the cylinder and disk, the cylinder is engaged in a sliding or reciprocating stroke across the disk and friction between the metal-metal contact is measured. This is used to evaluate the boundary regime friction characteristics of the oils.

Table 1

Additive	Oil 1	Oil 2	Oil 3	Oil 4	Oil 5	Oil 6	Oil 7	Oil 8	Oil 9
Additive Package ¹	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09	7.09 ⁶
Molybdenum Dithiocarbamate ²		0.23				0.11	0.11	0.045	0.045
Ashless Friction Modifier 1 ³					0.25				
Ashless Friction Modifier 2 ⁴			0.5				0.25		
Ashless Friction Modifier 3 ⁵				0.5					
Viscosity modifier ⁷	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Group II base oil	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance
SASH, mass% (ASTM D874)	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
P, mass% (ASTM D5185)	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
B, ppm (ASTM D5185)	100	100	100	100	100	100	100	100	100
Mo, ppm (ASTM D5185)	0	275	0	0	0	137	137	55	55
TBN (ASTM D2896)	6.63	6.73	7.07	6.63	6.63	6.68	6.90	6.65	6.61
N, mass% (ASTM D5291)	0.064	0.069	0.075	0.064	0.064	0.066	0.072	0.065	0.065
Ca, mass % (ASTM D5185)	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184	0.184
S, mass% (ASTM D2622)	0.249	0.299	0.249	0.249	0.249	0.274	0.274	0.259	0.259

¹ The additive package had the same composition for all oils in Table 1 and comprised a dispersant combination comprising non-borated and borated polyisobutylene succinimide dispersant, a calcium sulphonate detergent, a combination of hindered phenol and aromatic amine antioxidants, zinc dialkyldithiophosphate, silicone antifoam, pour point depressant and diluent oil.

² The molybdenum dithiocarbamate was a trimeric molybdenum dithiocarbamate additive available from Infineum UK Limited as Infineum C9455B.

³ Ashless friction modifier 1 was glycerol monooleate.

⁴ Ashless friction modifier 2 was a tallow ester of triethanol amine.

⁵ Ashless friction modifier 3 was octadecylsuccinic anhydride.

⁶ The "chloro" non-borated dispersant in the additive package of Oils 1-8 was replaced in the additive package of Oil 9 by "thermal" non-borated dispersant, at equivalent nitrogen content.

⁷ The viscosity modifier was a hydrogenated styrene-diene star polymer.

Example 1

[0118] Each of Oils 1-7 were tested in the HFRR and the average coefficient at each different temperature is set out in Table 2 below:

Table 2

Temperature, °C	Oil 1	Oil 2	Oil 3	Oil 4	Oil 5	Oil 6	Oil 7
40	0.122	0.117	0.120	0.117	0.123	0.119	0.122
60	0.135	0.124	0.132	0.125	0.136	0.125	0.138
80	0.153	0.128	0.146	0.132	0.144	0.144	0.148
100	0.158	0.113	0.150	0.138	0.148	0.136	0.127
120	0.161	0.122	0.154	0.145	0.154	0.135	0.115
140	0.162	0.122	0.157	0.149	0.155	0.131	0.118
160	0.162	0.096	0.140	0.140	0.136	0.125	0.090
180	0.159	0.099	0.138	0.141	0.134	0.130	0.063
200	0.158	0.100	0.136	0.139	0.140	0.126	0.064
220	0.156	0.095	0.141	0.145	0.144	0.124	0.078

[0119] This data is also graphically represented in Fig. 1.

[0120] Each of Oils 1-7 were also tested in the SRV and the average coefficient at each different temperature is set out in Table 3 below:

Table 3

Temperature, °C	Oil 1	Oil 2	Oil 3	Oil 4	Oil 5	Oil 6	Oil 7
60	0.170	0.082	0.161	0.162	0.160	0.134	0.135
80	0.165	0.090	0.161	0.163	0.160	0.147	0.152
100	0.167	0.125	0.162	0.165	0.161	0.149	0.154
120	0.171	0.135	0.161	0.167	0.164	0.151	0.153
140	0.173	0.127	0.161	0.166	0.167	0.151	0.150
160	0.171	0.111	0.167	0.164	0.169	0.147	0.135

[0121] This data is also graphically represented in Fig. 2

[0122] It can be seen from the data that as expected the oil with 0.23 mass% molybdenum dithiocarbamate has generally the lowest coefficient of friction and this reduces as the temperature increases. Halving the amount of molybdenum dithiocarbamate in Oil 6 increases the friction coefficient at higher temperature. Oils 3, 4 and 5 with ashless friction modifier and no molybdenum compound generally have a higher friction coefficient than the molybdenum-containing oils, though still perform better than the reference Oil 1, which contains neither ashless friction modifier nor molybdenum compound. It is noted that Oil 7, which contains half the amount of molybdenum dithiocarbamate and half the amount of ashless friction modifier 2 also performs well compared with Oil 2 with the higher molybdenum content.

[0123] Oils 6, 7 and 8 were tested in the JASO T 903:2016. Oil 8, which comprises a lower content of molybdenum achieved an MA2 rating, which is the highest friction level that can be achieved in this test and is desirable for good clutch operation. Oil 6, which has a higher molybdenum content achieved only an MB rating, which is the lowest rating in this test and not desirable for good functioning of a clutch assembly. These results are to be expected, since it is known that molybdenum compounds, especially molybdenum dithiocarbamates, are effective friction modifiers and at higher treat rates provide too much friction reduction for acceptable functioning of a clutch assembly.

[0124] Oil 7 though, which comprises the same higher molybdenum content as Oil 6, but additionally contains ashless friction modifier, achieves an MA1 rating. This is a good operational rating for a clutch assembly.

[0125] It can be seen from these results that use of the ashless friction modifier in combination with the molybdenum additive allows the use of higher treat rates of the molybdenum additive, which is beneficial for the engine lubrication,

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whilst still maintaining a clutch friction that is acceptable in use.

[0126] Thus, it can be seen from both the HFRR, SRV data and the JASO T 903:2016 data, that a combination of oil-soluble molybdenum compound and ashless organic friction modifier can be used in a lubricating oil composition provided to lubricate the engine crankcase and the clutch assembly from a common sump and provide a good coefficient of friction in the engine whilst maintaining acceptable friction in the clutch assembly.

Example 2

[0127] Oils 8 and 9, which differed only in the type of non-borated dispersant, were tested in the MTM. Figs. 3-6 show that Oil 9 with the "thermal" dispersant in place of the "chloro" dispersant exhibits reduced friction coefficient, which reduction is particularly marked at higher temperature.

Example 3

[0128] Three further oils, Oils 9-11, were blended and tested in the HFRR, SRV and JASO T 903:2016. The oils were compared to a commercial 10W-30 oil, composition unknown, which oil was measured as having an MA2 qualification in the JASO T 903:2016.

[0129] The composition of Oils 9-11 is set out in Table 4 below, the amounts being mass% active matter.

Table 4

Additive	Oil 9	Oil 10	Oil 11
Additive Package ⁸	7.9	7.9	7.9
Ashless Friction Modifier 2 ⁴	0.2	0.2	0.2
Molybdenum Dithiocarbamate ²	0.045	0.045	0.045
Viscosity Modifier ⁷	11	9.5	15.3
Group II base oil			Balance
Group III base oil	Balance	Balance	
SAE Viscosity Grade	5W-30	10W-30	10W-40
SASH, mass %, (ASTM D874)	0.688	0.688	0.688
P, ppm (ASTM D5185)	0.086	0.086	0.086
Mo, ppm (ASTM D5185)	55	55	55
S, mass% (ASTM D2622)	0.198	0.198	0.198
N, mass% (ASTM D5291)	0.08	0.08	0.08
B, ppm (ASTM D5185)	86	86	86
Ca, mass% (ASTM D5185)	0.148	0.148	0.148
TBN, (ASTM D2896)	6.59	6.59	6.59
⁸ The additive package was the same for each of Oils 9 to 11 and contained a combination of borated and non-borated polyisobutenylsuccinimide dispersants, calcium salicylate detergent, ZDDP, aromatic amine and hindered phenol antioxidant, silicone antifoam PPD and diluent oil. ² The molybdenum dithiocarbamate was a trimeric molybdenum dithiocarbamate additive available from Infineum UK Limited as Infineum C9455B. ⁴ Ashless friction modifier 2 was a tallow ester of triethanol amine. ⁷ The viscosity modifier was a hydrogenated styrene-diene star polymer.			

[0130] Oils 9 to 11 vary only in the amount of viscosity modifier and the base oil, in order to obtain the different SAE viscosity grades indicated.

[0131] The reference oil and each of Oils 9-11 were tested in the HFRR and the average coefficient at each different temperature is set out in Table 5 below:

Table 5

Temp (°C)	Reference	Oil 9	Oil 10	Oil 11
40	0.126	0.115	0.112	0.116
60	0.1335	0.124	0.119	0.125
80	0.154	0.143	0.138	0.144
100	0.1635	0.143	0.1395	0.1465
120	0.165	0.129	0.1305	0.139
140	0.166	0.101	0.0975	0.1335
160	0.157	0.148	0.150	0.147
180	0.158	0.133	0.136	0.144
200	0.157	0.091	0.093	0.097
220	0.160	0.086	0.089	0.089

[0132] The results are also represented graphically below, in Fig. 7.

[0133] The reference oil and each of Oils 9-11 were tested in the SRV and the average coefficient at each different temperature is set out in Table 6 below:

Table 6

Temp (°C)	Reference	Oil 9	Oil 10	Oil 11
60	0.164	0.160	0.160	0.159
80	0.159	0.156	0.156	0.154
100	0.163	0.158	0.158	0.157
120	0.168	0.160	0.160	0.159
140	0.172	0.158	0.159	0.159
160	0.174	0.148	0.147	0.152

[0134] The results are also represented graphically below, in Fig. 8.

[0135] It can be seen from the SRV data, that all of Oil 9-11 exhibited improved friction performance in the SRV compared to the commercial reference oil.

[0136] Oil 10 was also tested in the JASO T 903:2016 clutch friction test and found to have a MA2 performance level. Thus, Oil 10 exhibits comparable clutch friction performance to the commercial reference oil, but improved engine friction performance in the SRV.

Claims

1. A motorcycle having a four cycle engine and a transmission including a clutch assembly, the engine crankcase and the clutch assembly being lubricated by a lubricating oil composition provided from a common sump, wherein said lubricating oil composition comprises a major amount of oil of lubricating viscosity and minor amounts of (A) an oil soluble molybdenum compound and (B) an ashless organic friction modifier.
2. A motorcycle as claimed in Claim 1, wherein the lubricating oil composition comprises no more than 500 ppm of molybdenum from the oil-soluble molybdenum compound (A).
3. A motorcycle as claimed in claim 1 or 2, wherein the oil-soluble molybdenum compound consists of either a molybdenum dithiocarbamate or a molybdenum dithiophosphate or a mixture thereof, as the sole source of molybdenum atoms in the lubricating oil composition.

4. A motorcycle as claimed in any one of the preceding claims, wherein the lubricating oil composition wherein the ashless organic friction modifier (B) comprises at least one of (a) a nitrogen-free organic friction modifier comprising an ester formed by reacting carboxylic acids and anhydrides with alkanols, (b) an aminic or amine-based friction modifiers comprising alkoxylated mono- and di-amines, (c) an ester formed as the reaction product of (i) a tertiary amine of the formula $R_1R_2R_3N$ wherein R_1 , R_2 and R_3 represent aliphatic hydrocarbyl, preferably alkyl, groups having 1 to 6 carbon atoms, at least one of R_1 , R_2 and R_3 having a hydroxyl group, with (ii) a saturated or unsaturated fatty acid having 10 to 30 carbon atoms, or a mixture thereof.
5. A motorcycle as claimed in any one of the preceding claims, wherein the total amount of ashless organic friction modifier (B) in the lubricating oil composition does not exceed 5 mass %, based on the total mass of the lubricating oil composition and preferably does not exceed 2 mass % and more preferably does not exceed 0.5 mass %.
6. A motorcycle as claimed in any one of the preceding claims, wherein the lubricating oil composition further comprises an ashless dispersant additive, the ashless dispersant additive may comprise a major amount of an ashless dispersant made by the thermal process.
7. A motorcycle as claimed in any one of the preceding claims, wherein the lubricating oil composition further comprises metal-containing detergent, which metal containing detergent may be an alkali or alkaline earth metal sulfonate, phenate or salicylate.
8. A motorcycle as claimed in claim 7, wherein the alkali or alkaline earth metal salicylate is the only metal containing detergent in the lubricating oil composition.
9. A motorcycle as claimed in any one of the preceding claims, wherein the lubricating oil composition further comprises a viscosity modifier, which viscosity modifier comprises a major amount of a star polymer viscosity modifier.
10. A motorcycle as claimed in claim 9, wherein the viscosity modifier comprises one or more star polymer viscosity modifier as the only viscosity modifier in the lubricating oil composition.
11. A method of operating a motorcycle having a four cycle engine and a transmission including a clutch assembly, the engine crankcase and the clutch assembly being lubricating by a lubricating oil composition provided from a common sump, said method comprising supplying to the engine crankcase and clutch assembly a lubricating oil composition comprising a major amount of oil of lubricating viscosity and minor amounts of (A) an oil soluble molybdenum compound and (B) an ashless organic friction modifier.
12. A method of operating a motorcycle as claimed in Claim 11, wherein the lubricating oil composition comprises no more than 500 ppm of molybdenum from the oil-soluble molybdenum compound (A).
13. A method of operating a motorcycle as claimed in claim 11 or 12, wherein the oil-soluble molybdenum compound consists of either a molybdenum dithiocarbamate or a molybdenum dithiophosphate or a mixture thereof, as the sole source of molybdenum atoms in the lubricating oil composition.
14. A method of operating a motorcycle as claimed in any one of claims 11-13, wherein the lubricating oil composition wherein the ashless organic friction modifier (B) comprises at least one of (a) a nitrogen-free organic friction modifier comprising an ester formed by reacting carboxylic acids and anhydrides with alkanols, (b) an aminic or amine-based friction modifiers comprising alkoxylated mono- and di-amines, (c) an ester formed as the reaction product of (i) a tertiary amine of the formula $R_1R_2R_3N$ wherein R_1 , R_2 and R_3 represent aliphatic hydrocarbyl, preferably alkyl, groups having 1 to 6 carbon atoms, at least one of R_1 , R_2 and R_3 having a hydroxyl group, with (ii) a saturated or unsaturated fatty acid having 10 to 30 carbon atoms, or a mixture thereof.
15. A method of operating a motorcycle as claimed in any one of the claims 11-14, wherein the total amount of ashless organic friction modifier (B) in the lubricating oil composition does not exceed 5 mass %, based on the total mass of the lubricating oil composition and preferably does not exceed 2 mass % and more preferably does not exceed 0.5 mass %.
16. A method of operating a motorcycle as claimed in any one of claims 11-15, wherein the lubricating oil composition further comprises an ashless dispersant additive, which ashless dispersant additive is preferably made by a thermal process.

17. A method of operating a motorcycle as claimed in any one of claims 11-16, wherein the lubricating oil composition further comprises metal-containing detergent, which metal containing detergent may be an alkali or alkaline earth metal sulfonate, phenate or salicylate.
18. A method of operating a motorcycle as claimed in claim 17, wherein the alkali or alkaline earth metal salicylate is the only metal containing detergent in the lubricating oil composition.
19. A method of operating a motorcycle as claimed in any one of claims 11-18, wherein the lubricating oil composition further comprises a viscosity modifier, which viscosity modifier comprises a major amount of a star polymer viscosity modifier.
20. A lubricating oil composition comprising a major amount of oil of lubricating viscosity and minor amounts of (A) an oil soluble molybdenum compound and (B) an ashless organic friction modifier, which lubricating oil composition exhibits a JASO clutch friction of at least MA1 when measured according to the JASO T 903:2016 clutch friction test.
21. A lubricating oil composition according to any one of claims 20, wherein the lubricating oil composition comprises no more than 500 ppm of molybdenum from the oil-soluble molybdenum compound (A).
22. A lubricating oil composition according to claims 20 or 21, wherein the oil-soluble molybdenum compound consists of either a molybdenum dithiocarbamate or a molybdenum dithiophosphate or a mixture thereof, as the sole source of molybdenum atoms in the lubricating oil composition.
23. A lubricating oil composition according to any one of claims 20-22, wherein the lubricating oil composition wherein the ashless organic friction modifier (B) comprises at least one of (a) a nitrogen-free organic friction modifier comprising an ester formed by reacting carboxylic acids and anhydrides with alkanols, (b) an aminic or amine-based friction modifiers comprising alkoxyated mono- and di-amines, (c) an ester formed as the reaction product of (i) a tertiary amine of the formula $R_1R_2R_3N$ wherein R_1 , R_2 and R_3 represent aliphatic hydrocarbyl, preferably alkyl, groups having 1 to 6 carbon atoms, at least one of R_1 , R_2 and R_3 having a hydroxyl group, with (ii) a saturated or unsaturated fatty acid having 10 to 30 carbon atoms, or a mixture thereof.
24. A lubricating oil composition according to any one of claims 20-23, wherein the total amount of ashless organic friction modifier (B) in the lubricating oil composition does not exceed 5 mass %, based on the total mass of the lubricating oil composition and preferably does not exceed 2 mass % and more preferably does not exceed 0.5 mass %.
25. A lubricating oil composition according to any one of claims 20-24, wherein the lubricating oil composition further comprises an ashless dispersant additive, which ashless dispersant is preferably made by the thermal process.
26. A lubricating oil composition according to any one of claims 20-25, wherein the lubricating oil composition further comprises metal-containing detergent, which metal containing detergent may be an alkali or alkaline earth metal sulfonate, phenate or salicylate.
27. A lubricating oil composition as claimed in claim 26, wherein the metal-containing detergent comprises one or more alkali or alkaline earth metal salicylate is the only metal containing detergent in the lubricating oil composition.
28. A lubricating oil composition according to any one of claims 24-27, wherein the lubricating oil composition further comprises a viscosity modifier, which viscosity modifier comprises a major amount of a star polymer viscosity modifier.

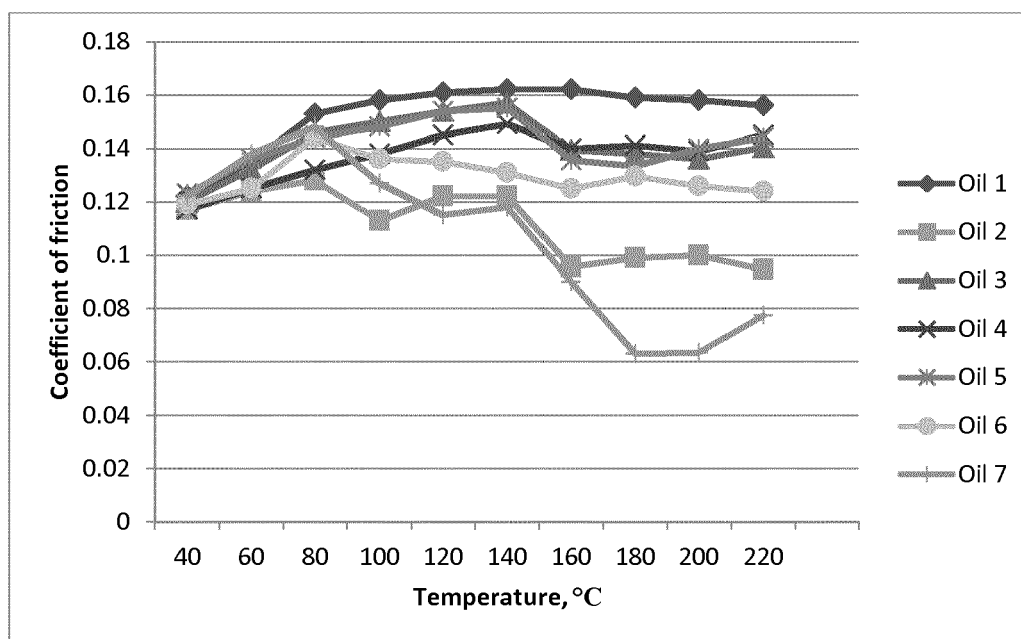


Fig. 1

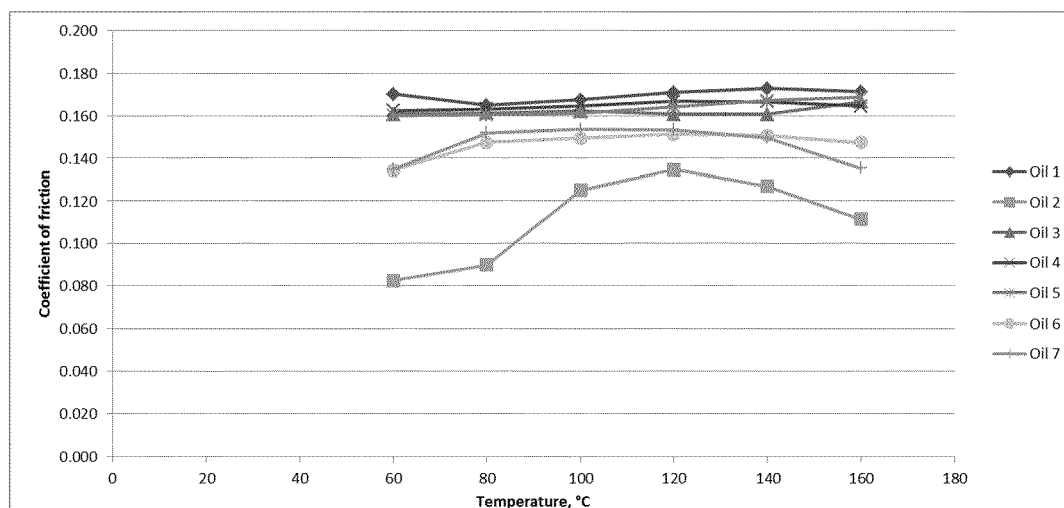


Fig. 2

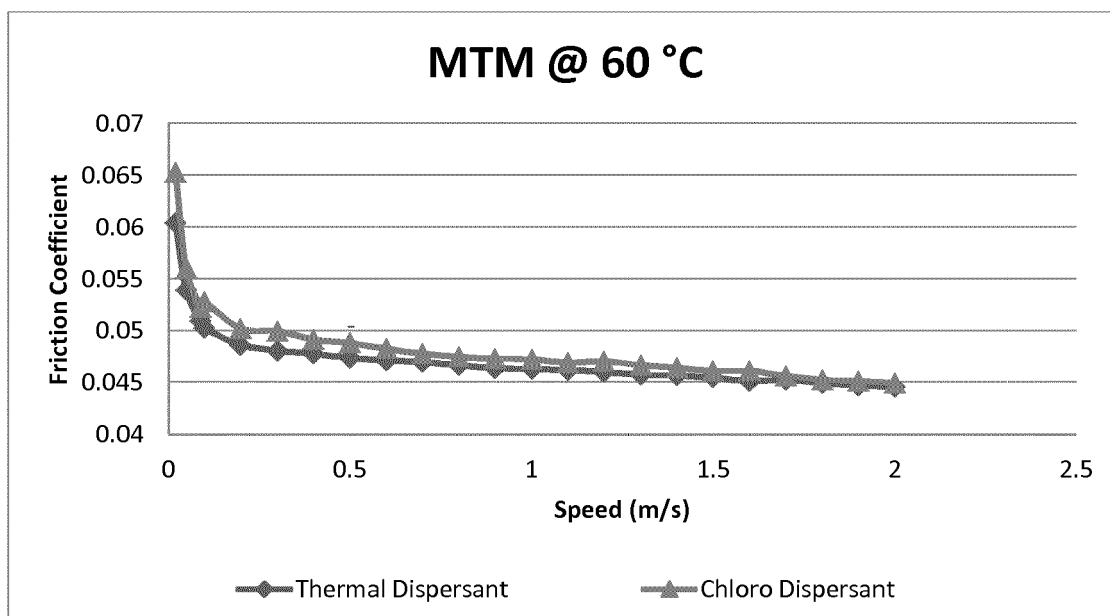


Fig. 3

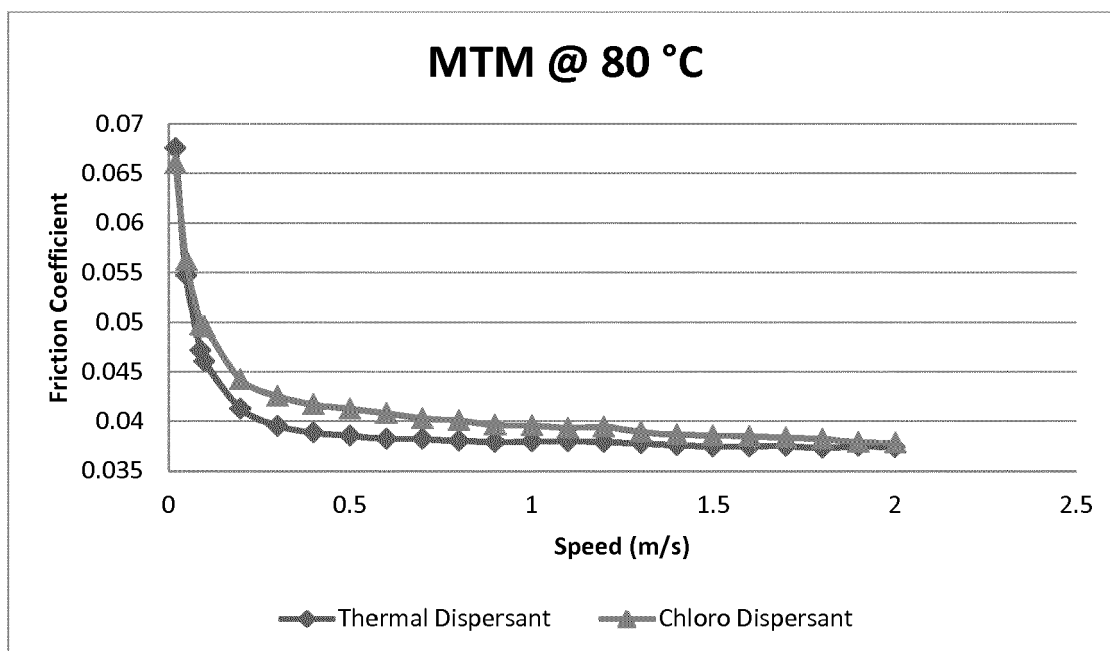


Fig. 4

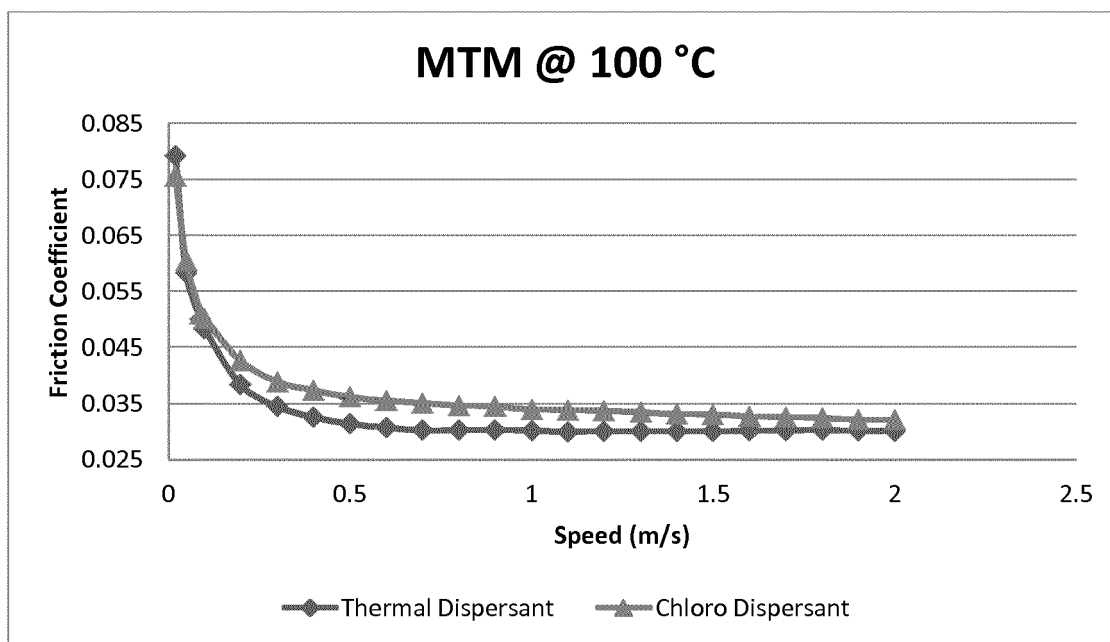


Fig. 5

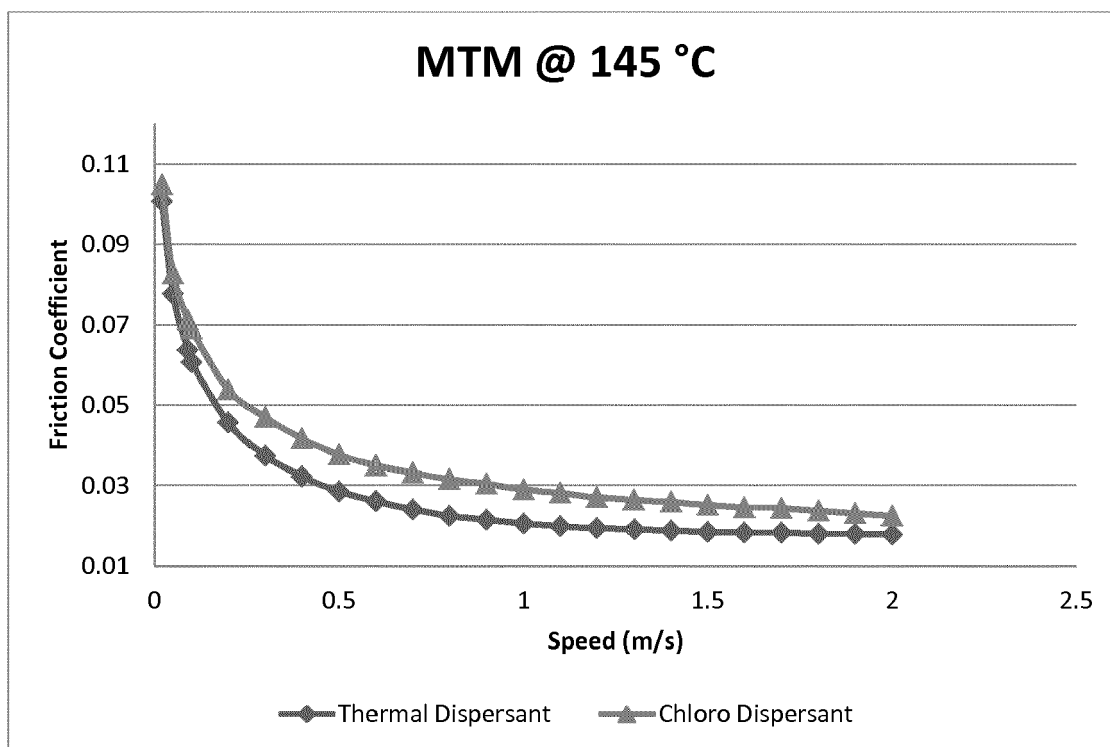


Fig. 6

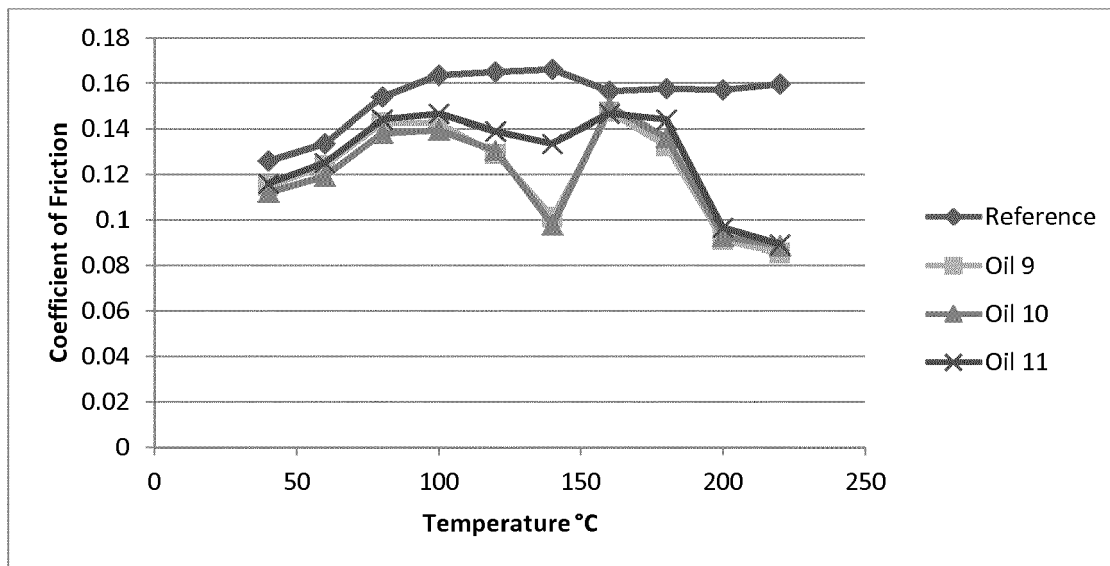


Fig. 7

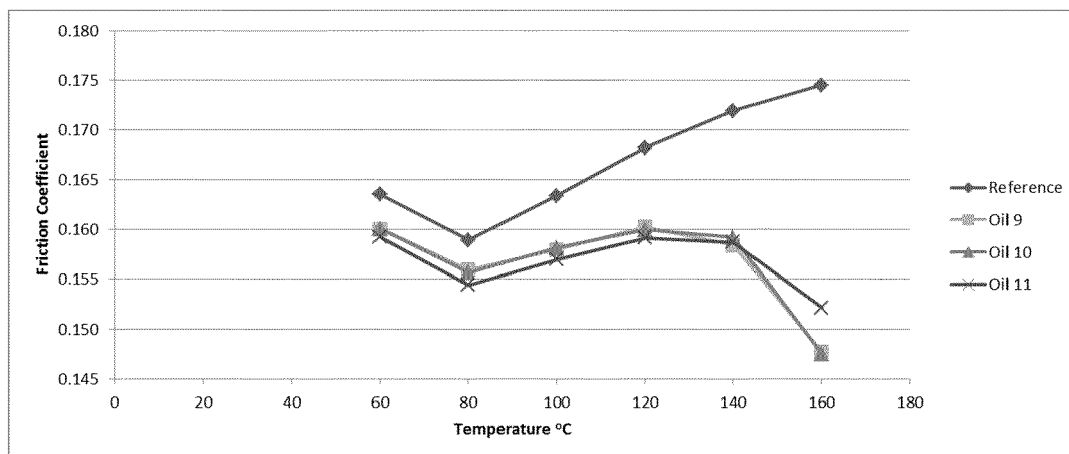


Fig. 8



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