

HIGH EFFICIENCY ENGINE OIL COMPOSITIONS

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FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to lubricating oil compositions for internal combustion engines wherein the compositions offer improved fuel economy.

BACKGROUND AND SUMMARY

[0002] Many different lubricating compositions have been tried in the prior art. Unfortunately, prior art lubricating oils often include added friction modifiers which have been discovered to sometimes cause detrimental effects on the vehicle's engine. Such detrimental effects may include, for example, increased deposit formation, increased seal failure, and/or decreased seal life. In addition, if friction modifiers are present in the oil with, for example, certain anti-wear additives, then the friction modifier may at least partially out-compete the anti-wear additive for limited surface sites. This could result in increased engine component wear because anti-wear films are not formed on at least some surfaces in need of wear protection.

[0003] What is needed are new cost-effective and efficient lubricating oil compositions that improve fuel economy. It would be desirable if such lubricating oil compositions did not need to employ friction modifiers that may negatively impact performance.

[0004] Advantageously, the present application pertains to low viscosity lubricating oil compositions that may significantly improve fuel economy and do not include significant amounts of added friction modifiers. In one embodiment, the application pertains to a lubricating oil composition for an internal combustion engine which exhibits improved fuel economy comprising a major amount of oil of lubricating viscosity, an alkaline earth metal sulfonate detergent providing 1200-2200ppm of metal to the lubricating oil composition, and a comb-shaped polymethacrylate viscosity modifier having a PSSI of less than 15. The

lubricating oil composition may be an 0W-8, an 0W-12, an 0W-16, or an 0W-20 SAE viscosity grade; be substantially free of a friction modifier; and may have a viscosity index of greater than 200.

[0005] In another embodiment the application relates to a method for improving fuel economy in an internal combustion engine comprising lubricating said engine with the aforementioned lubricating oil compositions and, if desired, operating said engine for improved fuel economy.

DETAILED DESCRIPTION

Definitions

[0006] The following terms will be used throughout the specification and will have the following meanings unless otherwise indicated.

[0007] The term “a major amount” of oil of lubricating viscosity refers to where the amount of base oil is at least 40 wt. % of the lubricating oil composition. In some embodiments, “a major amount” refers to an amount of the base oil more than 50 wt. %, more than 60 wt. %, more than 70 wt. %, more than 80 wt. %, or more than 90 wt. % of the lubricating oil composition.

[0008] In the following description, all numbers disclosed herein are approximate values, regardless of whether the word “about” or “approximate” is used in connection therewith. They may vary by 1 percent, 2 percent, 5 percent, or, sometimes, 10 to 20 percent.

[0009] The term “internal combustion engine” refers to any engine in which the combustion of a fuel occurs with an oxidizer in a combustion chamber which is a component of a working fluid flow circuit. Internal combustion engines are employed in hybrid vehicles and often operate at lower temperatures than internal combustion engines on traditional vehicles.

[0010] “HOB” refers to high overbased with a TBN above 250 on an actives basis and “LOB” refers to low overbased with a TBN below 100 on an actives basis.

[0011] The term "Total Base Number" or "TBN" refers to the level of alkalinity in an oil sample, which indicates the ability of the composition to continue to neutralize corrosive acids, in accordance with ASTM Standard No. D2896 or equivalent procedure. The test measures the change in electrical conductivity, and the results are expressed as mgKOH/g (the equivalent number of milligrams of KOH needed to neutralize 1 gram of a product). Therefore, a high TBN reflects strongly overbased products and, as a result, a higher base reserve for neutralizing acids.

[0012] Commonly used friction modifiers in engine oil application can be categorized into two: organic friction modifier such as glycerol monooleate and inorganic friction modifier such as molybdenum dithiocarbamates. There are many different types of organic or inorganic friction modifiers. Typically, organic friction modifiers are used in 0.1-1wt% range while inorganic modifier are in 100-1000ppm metal concentration range. The term "substantially free" means less than 0.1wt% for organic friction modifiers or less than 100ppm metal concentration when used in connection with "substantially free" of a friction modifier.

The Oil of Lubricating Viscosity

[0013] The lubricating oil compositions disclosed herein generally comprise at least one oil of lubricating viscosity. Any base oil known to a skilled artisan can be used as the oil of lubricating viscosity disclosed herein. Some base oils suitable for preparing the lubricating oil compositions have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapters 1 and 2 (1996); and A. Sequeria, Jr., "Lubricant Base Oil and Wax Processing," New York, Marcel Decker, Chapter 6, (1994); and D. V. Brock, Lubrication Engineering, Vol. 43, pages 184-5, (1987), all of which are incorporated herein by reference.

[0014] Generally, the amount of the base oil in the lubricating oil composition is a "a major amount" of oil of lubricating viscosity as defined above.

[0015] In certain embodiments, the base oil is or comprises any natural or synthetic lubricating base oil fraction. Some non-limiting examples of synthetic oils include oils, such as polyalphaolefins or PAOs, prepared from the polymerization of at least one alpha-olefin, such as ethylene, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases, such as the Fisher-Tropsch process.

[0016] In some embodiments, the base oil has a kinematic viscosity at 100° C. from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 centistokes (cSt) to about 20 cSt, or from about 5 cSt to about 16 cSt. The kinematic viscosity of the base oils or the lubricating oil compositions disclosed herein can be measured according to ASTM D 445, which is incorporated herein by reference.

[0017] In other embodiments, the base oil is or comprises a base stock or blend of base stocks. In further embodiments, the base stocks are manufactured using a variety of different processes including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. In some embodiments, the base stocks comprise a rerefined stock. In further embodiments, the rerefined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use.

[0018] In some embodiments, the base oil comprises one or more of the base stocks in one or more of Groups I-V as specified in the American Petroleum Institute (API) Publication 1509, Fourteen Edition, December 1996 (i.e., API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils), which is incorporated herein by reference. The API guideline defines a base stock as a lubricant component that may be manufactured using a variety of different processes. Groups I, II and III base stocks are mineral oils, each with specific ranges of the amount of saturates, sulfur content and viscosity index. Group IV base stocks are polyalphaolefins (PAO). Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

[0019] In some embodiments, the base oil comprises one or more of the base stocks in Group I, II, III, IV, V or a combination thereof. In other embodiments, the base oil comprises one or more of the base stocks in Group II, III, IV or a combination thereof. In further embodiments, the base oil comprises one or more of the base stocks in Group II, III, IV or a combination thereof wherein the base oil has a kinematic viscosity from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 cSt to about 20 cSt, or from about 5 cSt to about 16 cSt at 100° C.

[0020] The base oil may be selected from the group consisting of natural oils of lubricating viscosity, synthetic oils of lubricating viscosity and mixtures thereof. In some embodiments, the base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocrackate base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. In other embodiments, the base oil of lubricating viscosity includes natural oils, such as animal oils, vegetable oils, mineral oils (e.g., liquid petroleum oils and solvent treated or acid-treated mineral oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types), oils derived from coal or shale, and combinations thereof. Some non-limiting examples of animal oils include bone oil, lanolin, fish oil, lard oil, dolphin oil, seal oil, shark oil, tallow oil, and whale oil. Some non-limiting examples of vegetable oils include castor oil, olive oil, peanut oil, rapeseed oil, corn oil, sesame oil, cottonseed oil, soybean oil, sunflower oil, safflower oil, hemp oil, linseed oil, tung oil, oiticica oil, jojoba oil, and meadow foam oil. Such oils may be partially or fully hydrogenated.

[0021] In some embodiments, the synthetic oils of lubricating viscosity include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and inter-polymerized olefins, alkylbenzenes, polyphenyls, alkylated diphenyl ethers, alkylated diphenyl sulfides, as well as their derivatives, analogues and homologues thereof, and the like. In other embodiments, the synthetic oils include alkylene oxide polymers, interpolymers, copolymers and derivatives thereof wherein the terminal hydroxyl groups can be modified by esterification, etherification,

and the like. In further embodiments, the synthetic oils include the esters of dicarboxylic acids with a variety of alcohols. In certain embodiments, the synthetic oils include esters made from C₃ to C₁₂ monocarboxylic acids and polyols and polyol ethers. In further embodiments, the synthetic oils include tri-alkyl phosphate ester oils, such as tri-n-butyl phosphate and tri-isobutyl phosphate.

[0022] In some embodiments, the synthetic oils of lubricating viscosity include silicon-based oils (such as the polyakyl-, polyaryl-, polyalkoxy-, polyaryloxy-siloxane oils and silicate oils). In other embodiments, the synthetic oils include liquid esters of phosphorus-containing acids, polymeric tetrahydrofurans, polyalphaolefins, and the like.

[0023] Base oil derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base oil. Such wax isomerase oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

[0024] In further embodiments, the base oil comprises a poly-alpha-olefin (PAO). In general, the poly-alpha-olefins may be derived from an alpha-olefin having from about 2 to about 30, from about 4 to about 20, or from about 6 to about 16 carbon atoms. Non-limiting examples of suitable poly-alpha-olefins include those derived from octene, decene, mixtures thereof, and the like. These poly-alpha-olefins may have a viscosity from about 2 to about 15, from about 3 to about 12, or from about 4 to about 8 centistokes at 100° C. In some instances, the poly-alpha-olefins may be used together with other base oils such as mineral oils.

[0025] In further embodiments, the base oil comprises a polyalkylene glycol or a polyalkylene glycol derivative, where the terminal hydroxyl groups of the polyalkylene glycol may be modified by esterification, etherification, acetylation and the like. Non-limiting examples of suitable polyalkylene glycols include polyethylene glycol, polypropylene glycol, polyisopropylene glycol, and combinations thereof. Non-limiting examples of suitable

polyalkylene glycol derivatives include ethers of polyalkylene glycols (e.g., methyl ether of polyisopropylene glycol, diphenyl ether of polyethylene glycol, diethyl ether of polypropylene glycol, etc.), mono- and polycarboxylic esters of polyalkylene glycols, and combinations thereof. In some instances, the polyalkylene glycol or polyalkylene glycol derivative may be used together with other base oils such as poly- α -olefins and mineral oils.

[0026] In further embodiments, the base oil comprises any of the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, and the like) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, and the like). Non-limiting 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, dicicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the like.

[0027] In further embodiments, the base oil comprises a hydrocarbon prepared by the Fischer-Tropsch process. The Fischer-Tropsch process prepares hydrocarbons from gases containing hydrogen and carbon monoxide using a Fischer-Tropsch catalyst. These hydrocarbons may require further processing in order to be useful as base oils. For example, the hydrocarbons may be dewaxed, hydroisomerized, and/or hydrocracked using processes known to a person of ordinary skill in the art.

[0028] In further embodiments, the base oil comprises an unrefined oil, a refined oil, a rerefined oil, or a mixture thereof. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. Non-limiting examples of unrefined oils include shale oils obtained directly from retorting operations, petroleum oils obtained directly from primary distillation, and ester oils obtained directly from an esterification process

and used without further treatment. Refined oils are similar to the unrefined oils except the former have been further treated by one or more purification processes to improve one or more properties. Many such purification processes are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, and the like. Rerefined oils are obtained by applying to refined oils processes similar to those used to obtain refined oils. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally treated by processes directed to removal of spent additives and oil breakdown products.

Alkaline Earth Metal Sulfonate Detergent

[0029] The lubricating oil compositions typically comprise an alkaline earth metal sulfonate detergent. The alkaline earth metal sulfonate detergent is not particularly limited but in some embodiments comprises magnesium sulfonate detergent, a calcium sulfonate detergent, or a mixture thereof. In some embodiments the sulfonate detergent may be at least partially replaced or supplemented with a phenate based detergent.

[0030] The amount and type of alkaline earth metal sulfonate and/or phenate detergent may vary but typically is selected to provide at least about 1200, or at least about 1300, or at least about 1400 ppm of metal to the lubricating oil composition. On the other hand, the amount and type of alkaline earth metal sulfonate detergent is usually selected to provide less than about 2200, or less than about 2100, or less than about 2000 ppm of metal to the lubricating oil composition.

[0031] The lubricating oil composition may comprise a second detergent in addition to the alkaline earth metal detergent described above so long as the second detergent does not negatively affect the enhanced fuel efficiency of the compositions. Some non-limiting examples of suitable metal detergent include sulfurized or unsulfurized alkyl or alkenyl phenates, alkyl or alkenyl aromatic sulfonates, borated sulfonates, sulfurized or unsulfurized

metal salts of multi-hydroxy alkyl or alkenyl aromatic compounds, alkyl or alkenyl hydroxy aromatic sulfonates, sulfurized or unsulfurized alkyl or alkenyl naphthenates, metal salts of alkanolic acids, metal salts of an alkyl or alkenyl multiacid, and chemical and physical mixtures thereof. Other non-limiting examples of suitable metal detergents include metal sulfonates, phenates, salicylates, phosphonates, thiophosphonates and combinations thereof. The metal can be any metal suitable for making sulfonate, phenate, salicylate or phosphonate detergents. Non-limiting examples of suitable metals include alkali metals, alkaline metals and transition metals. In some embodiments, the metal is Ca, Mg, Ba, K, Na, Li or the like.

[0032] Some suitable detergents have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 3, pages 75-85 (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker, Chapter 4, pages 113-136 (2003), both of which are incorporated herein by reference.

[0033] The detergent may comprise at least one high overbased (TBN above 250 on an active basis) sulfonate detergent such as high overbased calcium sulfonate and at least one non-sulfonate detergent such as a phenate detergent.

[0034] Additional detergents that may be used include oil-soluble overbased sulfonate, non-sulfonate containing phenate, sulfurized phenates, salixarate, salicylate, saligenin, complex detergents and naphthenate detergents and other oil-soluble alkylhydroxybenzoates of a metal, particularly the alkali or alkaline earth metals, e.g., barium, 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 lubricant, and mixtures of calcium and/or magnesium with sodium.

[0035] Overbased metal detergents are generally produced by carbonating a mixture of hydrocarbons, detergent acid, for example: sulfonic acid, alkylhydroxybenzoate etc., metal oxide or hydroxides (for example calcium oxide or calcium hydroxide) and promoters such as

xylene, methanol and water. For example, for preparing an overbased calcium sulfonate, in carbonation, the calcium oxide or hydroxide reacts with the gaseous carbon dioxide to form calcium carbonate. The sulfonic acid is neutralized with an excess of CaO or Ca(OH)₂, to form the sulfonate.

[0036] Overbased detergents may be low overbased, e.g., an overbased salt having a TBN below 100 on an actives basis. In one aspect, the TBN of a low overbased salt may be from about 10, from about 20, or from about 30 to about 100. In another aspect, the TBN of a low overbased salt may be from about 30 to about 80. Overbased detergents may be medium overbased, e.g., an overbased salt having a TBN from about 100 to about 250 on an actives basis. In one aspect, the TBN of a medium overbased salt may be from about 100 to about 200. In another aspect, the TBN of a medium overbased salt may be from about 125 to about 175. Overbased detergents may be high overbased, e.g., an overbased salt having a TBN above 250 on an actives basis. In one aspect, the TBN of a high overbased salt may be from about 250 to about 800 on an actives basis.

[0037] In one aspect, the detergent can be one or more alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid. Suitable hydroxyaromatic compounds include mononuclear monohydroxy and polyhydroxy aromatic hydrocarbons having 1 to 4, and preferably 1 to 3, hydroxyl groups. Suitable hydroxyaromatic compounds include phenol, catechol, resorcinol, hydroquinone, pyrogallol, cresol, and the like.

Non-dispersant Comb Polymethacrylate

[0038] The non-dispersant comb polymethacrylate (comb PMA) is a comb-shaped polymer that can be used as a viscosity modifier or viscosity index improver. In one embodiment the comb PMA used herein has a Permanent Shear Stability Index (PSSI) of less than 15, or less than 10, or less than 5, or less than 1 according to ASTM D7109 (Kurt Orbahn Shear Stability).

[0039] In one embodiment, the non-dispersant comb PMA has a weight average molecular weight (Mw) of 300,000 g/mol to 600,000 g/mol, 350,000 g/mol to 550,000 g/mol, 375,000 g/mol to 500,000 g/mol, or 390,000 g/mol to 460,000 g/mol.

[0040] In one embodiment, the non-dispersant comb PMA has a number average molecular weight (Mn) of 35,000 g/mol to 105,000 g/mol, 45,000 g/mol to 95,000 g/mol, 55,000 g/mol to 85,000 g/mol, or 65,000 g/mol to 75,000 g/mol. In another embodiment, the non-dispersant comb PMA has a number average molecular weight (Mn) of 150,000 g/mol to 250,000 g/mol or 200,000 g/mol to 215,000 g/mol.

[0041] In one embodiment, the non-dispersant comb PMA has a Shear Stability Index (SSI) of 0.1 to 1.0, 0.2 to 0.9, or 0.3 to 0.8.

[0042] The non-dispersant comb PMA of the lubricating oil composition can be described as set forth in US 2017/0298287A1 and JP2019014802, the disclosures of which is incorporated herein by reference. The non-dispersant comb PMA can be provided by Viscoplex® Viscosity Index Improver 3-201 and/or 3-162, which are available from Evonik.

[0043] According to one embodiment, the non-dispersant comb PMA is provided by the compound referred to as Viscoplex® 3-201, which includes, as a main resin component, a comb PMA. This non-dispersant comb PMA has a weight average molecular weight (Mw) of 420,000 g/mol, a number average molecular weight (Mn) of 70,946 g/mol, and a Mw/Mn of 5.92. The compound has at least a constituent unit derived from a macromonomer having a Mn of 500 or more. The non-dispersant comb PMA is present in an amount of 19 wt. %, based on the total weight of the compound.

[0044] According to another embodiment, the non-dispersant comb PMA is provided by the compound referred to as Viscoplex® 3-162, which also includes, as a main resin component, a comb PMA. This non-dispersant comb PMA has a weight average molecular weight (Mw)

of 399,292 g/mol, a number average molecular weight (Mn) of 205,952 g/mol, a Mw/Mn of 1.94, and a Permanent Shear Stability Index (PSSI) of 0.6 as measured by ASTM D7109.

[0045] According to another embodiment, the non-dispersant comb PMA is provided by a combination of compounds, for example a combination of the Viscoplex® 3-201 and the Viscoplex® 3-162.

[0046] The non-dispersant comb PMA is typically present in an amount of 0.5 wt. % to 25 wt. %, 1 wt. % to 20 wt. %, 2 wt. % to 18 wt. %, 4 wt. % to 16 wt. %, or 5 wt. % to 15 wt. %, based on the total weight of the lubricating oil composition.

[0047] It has been unexpectedly discovered that non-dispersant comb PMA viscosity modifiers provide enhanced performance compared to other viscosity modifiers such as linear poly(meth)acrylates (PMA), olefin copolymers (OCP), and hydrogenated star-diene (HSD) type viscosity index improvers. Linear poly(meth)acrylate viscosity modifiers are generally synthesized by simple free-radical copolymerization of a mixture of different alkyl methacrylates. Unlike comb-type PMAs, conventional linear PMAs are characterized by predominantly short alkyl chain lengths present (typically 1-50 carbons) and the lack of long alkyl chain macromonomers which give comb polymers their characteristic shape. See U.S. Patent Nos. 3,607,749 and 8,778,857, and European Patent 0225,598. Olefin copolymer viscosity modifiers typically comprise ethylene and propylene and in some cases may contain a diene as a third monomer. See, e.g., U.S. Patent Nos. 7,402,235 and 5,391,617, and European Patent 0638,611. Hydrogenated styrene-diene type viscosity index improvers can be prepared by copolymerizing styrene and butadiene and hydrogenating the unsaturated copolymers. The hydrogenated styrene-diene copolymers can be linear block copolymers or star-shaped. See U.S. Pat. Nos. 4,116,917, 3,772,196 and 4,788,316 for examples of HSD copolymers as viscosity modifiers in lubricating oils.

Other Properties of the Lubrication Oil Compositions of the Present Application

[0048] The lubricating oil compositions of the present application are generally either an 0W-8, an 0W-12, an 0W-16, or an 0W-20 SAE viscosity grade.

[0049] The lubricating oil compositions generally have a viscosity index of greater than about 200, or greater than about 205, or greater than about 210, or greater than about 220, or greater than about 240 up to about 270 or more.

[0050] The lubricating oil compositions generally improve fuel economy. The degree of fuel economy improvement (FEI as described below) may vary depending upon the specific lubricating oil composition, the engine employed, and other factors. In some cases, the compositions described herein exhibit a fuel economy improvement (FEI) of at least about 1%, or at least about 1.5%, or at least about 2% up to as much as 4% or higher.

Other Additives May Be Added that Are Consistent with the Above Ingredients and Properties

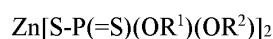
[0051] To the extent that it is consistent with the ingredients and properties of the lubricating composition described above, the lubricating oil composition may further comprise at least an additive or a modifier (hereinafter designated as "additive") that can impart or improve any desirable property of the lubricating oil composition. Any additive known to a person of ordinary skill in the art may be used in the lubricating oil compositions disclosed herein. Some suitable additives have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition. London, Springer, (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker (2003), both of which are incorporated herein by reference. In some embodiments, the additive can be selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof.

[0052] A particularly suitable combination of additives comprises glycerol in the amounts described above, a dispersant additive such as ethylene carbonate post treated bissuccinimide, an antiwear additive such as zinc dialkyl dithiophosphate such as one derived from a primary alcohol, and a detergent composition as described above comprising at least one high overbased sulfonate detergent (e.g., a high overbased calcium sulfonate) and at least one non-sulfonate detergent (e.g., a phenate detergent). The zinc dialkyl dithiophosphate is a primary, secondary zinc dialkyl dithiophosphate, or a combination thereof and may be present at 3 wt. % or less (e.g., 0.1 to 1.5 wt. %, or 0.5 to 1.0 wt. %) of the lubricating oil composition. The dispersant such as ethylene carbonate post treated bissuccinimide may be present at 0.1 to 10 wt. % (e.g., 0.5 to 8, 0.7 to 7, 0.7 to 6, 0.7 to 6, 0.7 to 5, 0.7 to 4 wt. %), based on the total weight of the lubricating oil composition.

[0053] In general, the concentration of each of the additives in the lubricating oil composition, when used, may range from about 0.001 wt. % to about 10 wt. %, from about 0.01 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 2.5 wt. %, based on the total weight of the lubricating oil composition. Further, the total amount of the additives in the lubricating oil composition may range from about 0.001 wt. % to about 20 wt. %, from about 0.01 wt. % to about 10 wt. %, or from about 0.1 wt. % to about 5 wt. %, based on the total weight of the lubricating oil composition.

Antiwear agents

[0054] Optionally, the lubricating oil composition disclosed herein can comprise one or more antiwear agents. Antiwear agents reduce wear of metal parts. Suitable anti-wear agents include dihydrocarbyl dithiophosphate metal salts such as zinc dihydrocarbyl dithiophosphates (ZDDP) of the following structure:



wherein R^1 and R^2 may be the same or different hydrocarbyl radicals having from 1 to 18 (e.g.,

2 to 12) carbon atoms and including radicals such as alkyl, alkenyl, aryl, arylalkyl, alkaryl and cycloaliphatic radicals. Particularly preferred as R^1 and R^2 groups are alkyl groups having from 2 to 8 carbon atoms (e.g., the alkyl radicals may be ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, n-pentyl, isopentyl, n-hexyl, isohexyl, 2-ethylhexyl). In order to obtain oil solubility, the total number of carbon atoms (i.e., $R^1 + R^2$) will be at least 5. The zinc dihydrocarbyl dithiophosphate can therefore comprise zinc dialkyl dithiophosphates. The zinc dialkyl dithiophosphate is a primary, secondary zinc dialkyl dithiophosphate, or a combination thereof. ZDDP may be present at 3 wt. % or less (e.g., 0.1 to 1.5 wt. %, or 0.5 to 1.0 wt %) of the lubricating oil composition.

Dispersants

[0055] Optionally, the lubricating oil composition disclosed herein can further comprise a dispersant. Dispersants maintain in suspension materials resulting from oxidation during engine operation that are insoluble in oil, thus preventing sludge flocculation and precipitation or deposition on metal parts. Dispersants useful herein include nitrogen-containing, ashless (metal-free) dispersants known to be effective to reduce formation of deposits upon use in gasoline and diesel engines. Suitable dispersants include hydrocarbyl succinimides, hydrocarbyl succinamides, mixed ester/amides of hydrocarbyl-substituted succinic acid, hydroxyesters of hydrocarbyl-substituted succinic acid, and Mannich condensation products of hydrocarbyl-substituted phenols, formaldehyde and polyamines. Also suitable are condensation products of polyamines and hydrocarbyl-substituted phenyl acids. Mixtures of these dispersants can also be used.

[0056] Basic nitrogen-containing ashless dispersants are well-known lubricating oil additives and methods for their preparation are extensively described in the patent literature. Preferred dispersants are the alkenyl succinimides and succinamides where the alkenyl-substituent is a long-chain of preferably greater than 40 carbon atoms. These materials are readily made by

reacting a hydrocarbyl-substituted dicarboxylic acid material with a molecule containing amine functionality. Examples of suitable amines are polyamines such as polyalkylene polyamines, hydroxy-substituted polyamines and polyoxyalkylene polyamines. As is known in the art, the dispersants may be post-treated (e.g., with a boronating agent, ethylene carbonate, or a cyclic carbonate). Nitrogen-containing ashless (metal-free) dispersants are basic, and contribute to the TBN of a lubricating oil composition to which they are added, without introducing additional sulfated ash. Dispersants may be present at 0.1 to 10 wt. % (e.g., 0.5 to 8, 0.7 to 7, 0.7 to 6, 0.7 to 6, 0.7 to 5, 0.7 to 4 wt. %), based on an actives level, of the lubricating oil composition. Nitrogen from the dispersants is present from greater than 0.0050 to 0.30 wt. % (e.g., greater than 0.0050 to 0.10 wt. %, 0.0050 to 0.080 wt. %, 0.0050 to 0.060 wt. %, 0.0050 to 0.050 wt. %, 0.0050 to 0.040 wt. %, 0.0050 to 0.030 wt. %) based on the weight of the dispersants in the finished oil.

Antioxidants

[0057] Optionally, the lubricating oil composition disclosed herein can further comprise an additional antioxidant that can reduce or prevent the oxidation of the base oil. Any antioxidant known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable antioxidants include amine-based antioxidants (e.g., alkyl diphenylamines, phenyl- α -naphthylamine, alkyl or aralkyl substituted phenyl- α -naphthylamine, alkylated p-phenylene diamines, tetramethyl-diaminodiphenylamine and the like), phenolic antioxidants (e.g., 2-tert-butylphenol, 4-methyl-2,6-di-tert-butylphenol, 2,4,6-tri-tert-butylphenol, 2,6-di-tert-butyl-p-cresol, 2,6-di-tert-butylphenol, 4,4'-methylenebis-(2,6-di-tert-butylphenol), 4,4'-thiobis(6-di-tert-butyl-o-cresol) and the like), sulfur-based antioxidants (e.g., dilauryl-3,3'-thiodipropionate, sulfurized phenolic antioxidants and the like), phosphorous-based antioxidants (e.g., phosphites and the like), zinc dithiophosphate, oil-soluble copper compounds and combinations thereof. The amount of the antioxidant may vary

from about 0.01 wt. % to about 10 wt. %, from about 0.05 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 3 wt. %, based on the total weight of the lubricating oil composition. Some suitable antioxidants have been described in Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York. Marcel Dekker, Chapter 1, pages 1-28 (2003), which is incorporated herein by reference.

Friction Modifiers

As described above, the lubricating oil compositions disclosed herein are generally substantially free of a friction modifier. "Substantially free" is defined above as comprising less than about 50 ppm. In some instances the lubricating oil compositions disclosed herein comprises less than about 25 ppm or even 0 ppm of a friction modifier. Friction modifiers that are typically excluded from the lubricating oil compositions disclosed herein are fatty carboxylic acids; derivatives (e.g., alcohol, esters, borated esters, amides, metal salts and the like) of fatty carboxylic acid; mono-, di- or tri-alkyl substituted phosphoric acids or phosphonic acids; derivatives (e.g., esters, amides, metal salts and the like) of mono-, di- or tri-alkyl substituted phosphoric acids or phosphonic acids; mono-, di- or tri-alkyl substituted amines; mono- or di-alkyl substituted amides; alkoxyated fatty amines; borated fatty epoxides; fatty phosphites, fatty epoxides, fatty amines, borated alkoxyated fatty amines, metal salts of fatty acids, fatty acid amides, glycerol esters, borated glycerol esters; fatty imidazolines; reaction products of a C₄ to C₇₅, or a C₆ to C₂₄, or a C₆ to C₂₀, fatty acid ester and a nitrogen-containing compound selected from the group consisting of ammonia, and an alkanolamine; molybdenum dithiocarbamates (MoDTC); molybdenum dithiophosphates (MoDTP); molybdenum amines; molybdenum alcoholates; and molybdenum alcohol-amides.¶

Pour Point Depressants

[0058] The lubricating oil composition disclosed herein can optionally comprise a pour point depressant that can lower the pour point of the lubricating oil composition. Any pour point

depressant known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable pour point depressants include polymethacrylates, alkyl acrylate polymers, alkyl methacrylate polymers, di(tetra-paraffin phenol)phthalate, condensates of tetra-paraffin phenol, condensates of a chlorinated paraffin with naphthalene and combinations thereof. In some embodiments, the pour point depressant comprises an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and phenol, polyalkyl styrene or the like. The amount of the pour point depressant may vary from about 0.01 wt. % to about 10 wt. %, from about 0.05 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 3 wt. %, based on the total weight of the lubricating oil composition. Some suitable pour point depressants have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 6, pages 187-189 (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker, Chapter 11, pages 329-354 (2003), both of which are incorporated herein by reference.

Demulsifiers

[0059] The lubricating oil composition disclosed herein can optionally comprise a demulsifier that can promote oil-water separation in lubricating oil compositions that are exposed to water or steam. Any demulsifier known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable demulsifiers include anionic surfactants (e.g., alkyl-naphthalene sulfonates, alkyl benzene sulfonates and the like), nonionic alkoxylated alkylphenol resins, polymers of alkylene oxides (e.g., polyethylene oxide, polypropylene oxide, block copolymers of ethylene oxide, propylene oxide and the like), esters of oil soluble acids, polyoxyethylene sorbitan ester and combinations thereof. The amount of the demulsifier may vary from about 0.01 wt. % to about 10 wt. %, from about 0.05 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 3 wt. %, based on the total weight of the lubricating oil composition. Some suitable demulsifiers have been described in Mortier et al.,

"Chemistry and Technology of Lubricants," 2nd Edition. London, Springer, Chapter 6, pages 190-193 (1996), which is incorporated herein by reference.

Foam Inhibitors

[0060] The lubricating oil composition disclosed herein can optionally comprise a foam inhibitor or an anti-foam that can break up foams in oils. Any foam inhibitor or anti-foam known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable anti-foams include silicone oils or polydimethylsiloxanes, fluorosilicones, alkoxyated aliphatic acids, polyethers (e.g., polyethylene glycols), branched polyvinyl ethers, alkyl acrylate polymers, alkyl methacrylate polymers, polyalkoxyamines and combinations thereof. In some embodiments, the anti-foam comprises glycerol monostearate, polyglycol palmitate, a trialkyl monothiophosphate, an ester of sulfonated ricinoleic acid, benzoylacetone, methyl salicylate, glycerol monooleate, or glycerol dioleate. The amount of the anti-foam may vary from about 0.01 wt. % to about 5 wt. %, from about 0.05 wt. % to about 3 wt. %, or from about 0.1 wt. % to about 1 wt. %, based on the total weight of the lubricating oil composition. Some suitable anti-foams have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 6, pages 190-193 (1996), which is incorporated herein by reference.

Corrosion Inhibitors

[0061] The lubricating oil composition disclosed herein can optionally comprise a corrosion inhibitor that can reduce corrosion. Any corrosion inhibitor known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable corrosion inhibitor include half esters or amides of dodecylsuccinic acid, phosphate esters, thiophosphates, alkyl imidazolines, sarcosines and combinations thereof. The amount of the corrosion inhibitor may vary from about 0.01 wt. % to about 5 wt. %, from about 0.05 wt. % to about 3 wt. %, or from about 0.1 wt. % to about 1 wt. %, based on the total weight of

the lubricating oil composition. Some suitable corrosion inhibitors have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 6, pages 193-196 (1996), which is incorporated herein by reference.

Extreme Pressure Agents

[0062] The lubricating oil composition disclosed herein can optionally comprise an extreme pressure (EP) agent that can prevent sliding metal surfaces from seizing under conditions of extreme pressure. Any extreme pressure agent known by a person of ordinary skill in the art may be used in the lubricating oil composition. Generally, the extreme pressure agent is a compound that can combine chemically with a metal to form a surface film that prevents the welding of asperities in opposing metal surfaces under high loads. Non-limiting examples of suitable extreme pressure agents include sulfurized animal or vegetable fats or oils, sulfurized animal or vegetable fatty acid esters, fully or partially esterified esters of trivalent or pentavalent acids of phosphorus, sulfurized olefins, dihydrocarbyl polysulfides, sulfurized Diels-Alder adducts, sulfurized dicyclopentadiene, sulfurized or co-sulfurized mixtures of fatty acid esters and monounsaturated olefins, co-sulfurized blends of fatty acid, fatty acid ester and alpha-olefin, functionally-substituted dihydrocarbyl polysulfides, thia-aldehydes, thia-ketones, epithio compounds, sulfur-containing acetal derivatives, co-sulfurized blends of terpene and acyclic olefins, and polysulfide olefin products, amine salts of phosphoric acid esters or thiophosphoric acid esters and combinations thereof. The amount of the extreme pressure agent may vary from about 0.01 wt. % to about 5 wt. %, from about 0.05 wt. % to about 3 wt. %, or from about 0.1 wt. % to about 1 wt. %, based on the total weight of the lubricating oil composition. Some suitable extreme pressure agents have been described in Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker, Chapter 8, pages 223-258 (2003), which is incorporated herein by reference.

Rust Inhibitors

[0063] The lubricating oil composition disclosed herein can optionally comprise a rust inhibitor that can inhibit the corrosion of ferrous metal surfaces. Any rust inhibitor known by a person of ordinary skill in the art may be used in the lubricating oil composition. Non-limiting examples of suitable rust inhibitors include oil-soluble monocarboxylic acids (e.g., 2-ethylhexanoic acid, lauric acid, myristic acid, palmitic acid, oleic acid, linoleic acid, linolenic acid, behenic acid, cerotic acid and the like), oil-soluble polycarboxylic acids (e.g., those produced from tall oil fatty acids, oleic acid, linoleic acid and the like), alkenylsuccinic acids in which the alkenyl group contains 10 or more carbon atoms (e.g., tetrapropenylsuccinic acid, tetradecenylsuccinic acid, hexadecenylsuccinic acid, and the like); long-chain alpha,omega-dicarboxylic acids having a molecular weight in the range of 600 to 3000 daltons and combinations thereof. The amount of the rust inhibitor may vary from about 0.01 wt. % to about 10 wt. %, from about 0.05 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 3 wt. %, based on the total weight of the lubricating oil composition.

[0064] Other non-limiting examples of suitable rust inhibitors include nonionic polyoxyethylene surface active agents such as polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonyl phenyl ether, polyoxyethylene octyl phenyl ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monostearate, polyoxyethylene sorbitol mono-oleate, and polyethylene glycol mono-oleate. Further non-limiting examples of suitable rust inhibitor include stearic acid and other fatty acids, dicarboxylic acids, metal soaps, fatty acid amine salts, metal salts of heavy sulfonic acid, partial carboxylic acid ester of polyhydric alcohol, and phosphoric ester.

Multifunctional Additives

[0065] In some embodiments, the lubricating oil composition comprises at least a multifunctional additive. Some non-limiting examples of suitable multifunctional additives include sulfurized oxymolybdenum dithiocarbamate, sulfurized oxymolybdenum

organophosphorodithioate, oxymolybdenum monoglyceride, oxymolybdenum diethylate amide, amine-molybdenum complex compound, and sulfur-containing molybdenum complex compound.

Viscosity Modifiers

[0066] In certain embodiments, the lubricating oil composition comprises at least a viscosity modifier. Some non-limiting examples of suitable viscosity modifiers include polymethacrylate type polymers, ethylene-propylene copolymers, styrene-isoprene copolymers, hydrated styrene-isoprene copolymers, polyisobutylene, and dispersant type viscosity modifiers.

Metal Deactivators

[0067] In some embodiments, the lubricating oil composition comprises at least a metal deactivator. Some non-limiting examples of suitable metal deactivators include disalicylidene propylenediamine, triazole derivatives, thiadiazole derivatives, and mercaptobenzimidazoles.

Additive Concentrate Formulations

[0068] The additives disclosed herein may be in the form of an additive concentrate having more than one additive. The additive concentrate may comprise a suitable diluent, such as a hydrocarbon oil of suitable viscosity. Such diluent can be selected from the group consisting of natural oils (e.g., mineral oils), synthetic oils and combinations thereof. Some non-limiting examples of the mineral oils include paraffin-based oils, naphthenic-based oils, asphaltic-based oils and combinations thereof. Some non-limiting examples of the synthetic base oils include polyolefin oils (especially hydrogenated alpha-olefin oligomers), alkylated aromatic, polyalkylene oxides, aromatic ethers, and carboxylate esters (especially diester oils) and combinations thereof. In some embodiments, the diluent is a light hydrocarbon oil, both natural or synthetic. Generally, the diluent oil can have a viscosity from about 13 centistokes to about 35 centistokes at 40.degree. C.

[0069] Generally, it is desired that the diluent readily solubilizes the lubricating oil soluble additive and provides an oil additive concentrate that is readily soluble in the lubricant base oil stocks or fuels. In addition, it is desired that the diluent not introduce any undesirable characteristics, including, for example, high volatility, high viscosity, and impurities such as heteroatoms, to the lubricant base oil stocks and thus, ultimately to the finished lubricant or fuel.

[0070] The present application further provides an oil soluble additive concentrate composition comprising an inert diluent and from 2.0% to 90% by weight, preferably 10% to 50% by weight based on the total concentrate, of an oil soluble additive composition according to the present application.

[0071] The oil lubricating compositions comprising the additives described above may be employed in a method for improving fuel economy in an internal combustion engine comprising lubricating said engine with the lubricating oil composition comprising the additives and operating the engine.

[0072] The following examples are presented to exemplify embodiments but are not intended to limit the application to the specific embodiments set forth. Unless indicated to the contrary, all parts and percentages are by weight. All numerical values are approximate. When numerical ranges are given, it should be understood that embodiments outside the stated ranges may still fall within the scope of the application. Specific details described in each example should not be construed as necessary features.

Examples

[0073] The following examples are intended for illustrative purposes only and do not limit in any way the scope.

Example 1

[0074] An SAE 0W-8 lubricating oil was preparing by blending the following components together with a 2.5 cSt Group III base oil:

- A) 3.5 wt% of a succinimide dispersant
- B) 1700 ppm in terms of calcium content of an overbased calcium sulfonate detergent with a TBN of 410 mg KOH/g
- C) 750 ppm in terms of phosphorus content of a secondary ZnDTP
- D) 1.0 wt% of a phenolic antioxidant
- E) 7.1 wt% of a comb-type PMA viscosity modifier
- F) 5 ppm of a silicon-based foam inhibitor

The lubricating oil composition of example 1 had a KV100 of 4.34 cSt, a KV40 of 13.43, and a viscosity index of 272.

Comparative Example 1

[0075] The lubricating oil of comparative example 1 was formulated identically to example 1, except that the comb-type PMA viscosity modifier was replaced with 3.78 wt% of a linear dispersant PMA viscosity modifier. The lubricating oil composition of comparative example 1 had a KV100 of 4.80 cSt, a KV40 of 17.12, and a viscosity index of 226.

Comparative Example 2

[0076] The lubricating oil of comparative example 2 was formulated identically to example 1, except that the comb-type PMA viscosity modifier was replaced with 5.78 wt% of a olefin copolymer viscosity modifier. In addition, 0.40 wt% of a pour point depressant was added. The lubricating oil composition of comparative example 2 had a KV100 of 4.74 cSt, a KV40 of 19.65, and a viscosity index of 171.

Comparative Example 3

[0077] The lubricating oil of comparative example 3 was formulated identically to example 1, except that the calcium sulfonate detergent was replaced with an equal amount (on a calcium

basis) of calcium salicylate detergent with a TBN of 410 mg KOH/g. The lubricating oil composition of comparative example 3 had a KV100 of 4.37 cSt, a KV40 of 13.48, and a viscosity index of 275.

Comparative Example 4

[0078] The lubricating oil of comparative example 4 was formulated identically to example 1, except that in addition, 70ppm, in terms of boron, of a borated ester friction modifier was blended into the composition.

Comparative Example 5

[0079] The lubricating oil of comparative example 5 was formulated identically to example 1, except that in addition 660 ppm, in terms of molybdenum, of MoDTC was blended into the composition.

Example 2

[0080] The lubricating oil of example 2 was formulated identically to example 1, except that a 4 cSt Group III base oil was used instead to produce a lubricating oil composition with an SAE 0W-16 viscosity grade. The lubricating oil composition of example 2 had a KV100 of 6.29 cSt, a KV40 of 26.02, and a viscosity index of 208.

Comparative Example 6

[0081] The lubricating oil of comparative example 6 was formulated identically to example 2, except that the calcium sulfonate detergent was replaced with an equal amount (on a calcium basis) of calcium salicylate detergent with a TBN of 410 mg KOH/g. The lubricating oil composition of comparative example 6 had a KV100 of 6.32 cSt, a KV40 of 25.90, and a viscosity index of 211.

Fuel Economy Test in Toyota 2ZR-FXE (JASO M366)

[0082] The lubricating oil compositions above were tested for their fuel economy performance in a gasoline motored engine (Toyota 2ZR-FXE 1.8L L-4). The detailed configuration of the

test equipment and conditions can be found in SAE paper 2019-01-2296 Jikuya, H., Mori, S., Yamamori, K., and Hirano, S., "Development of Firing Fuel Economy Engine Dyno Test Procedure for JASO Ultra Low Viscosity Engine Oil Standard (JASO GLV-1)," SAE Technical Paper 2019-01-2296, 2019, which paper is hereby incorporated by reference. The test oils are pre-conditioned in the engine operating at 1350 rpm for 10 hours at an oil temperature of 88 °C. The fuel consumption of the test oils are measured over a 4-hour period, and compared against the fuel consumption of a baseline calibration (BC) oil.

[0083] The BC oil used in the test method described above is different from JASO BC oil and the viscometric of the BC oil is shown below.

Typical value	BC oil
KV100 (cSt)	7.5
KV40 (cSt)	43.4
HTHS150 (mPas)	2.6
HTHS100 (mPas)	6.0

[0084] The fuel economy improvement (FEI) is calculated for the candidate oil test as relative improvement (% change) to the average of two BC oils as shown below. A higher FEI value indicates overall better fuel economy performance.

$$[TFC] = \sum_{i=1}^6 \left([FC_i] \times \frac{[Power_i]}{[Nom Power_i]} \times [wt. Factor_i] \right)$$

TFC : Total Fuel Consumption (kg/h)

FC_i : Fuel Consumption rate at stage- i (kg/h)

$Power_i$: Actual Power Output at stage- i (kW)

$Nom Power_i$: Nominal Power Output at stage- i (kW)

$$[FEI(\%)] = \frac{([TFCBCB] + [TFCBCA]) \div 2 - [TFCAN]}{([TFCBCB] + [TFCBCA]) \div 2} \times 100$$

FEI : Fuel Economy Improvement (%)

TFCBCB : TFC of the BC oil before the candidate test oil (kg/h)

TFCCAN : TFC of the candidate test oil (kg/h)

TFCBCA : TFC of the BC oil after the candidate test oil (kg/h)

[0085] Table 1

	Example 1	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Example 2	Comp. Ex. 6
SAE viscosity grade	0W-8	0W-8	0W-8	0W-8	0W-8	0W-8	0W-16	0W-16
Detergent Type	Sulfonate	Sulfonate	Sulfonate	Salicylate	Sulfonate	Sulfonate	Sulfonate	Salicylate
Moly from FM (ppm)	0	0	0	0	0	660	0	0
Boated ester friction modifier	0	0	0	0	0.3	0	0	0
Viscosity Modifier	Comb PMA	linear d. PMA	OCP	Comb PMA	Comb PMA	Comb PMA	Comb PMA	Comb PMA
KV100	4.34	4.80	4.74	4.37	4.36	4.45	6.29	6.32
KV40	13.43	17.12	19.65	13.48	13.48	13.67	26.02	25.90
HTHS@ 150°C	1.74	1.70	1.73	1.76	1.74	1.74	2.36	2.37
Toyota 2ZR FXE FEI (%)	2.13	1.19	1.60	1.67	1.93	1.82	1.13	0.83

[0086] The FEI results of example 1 versus comparative examples 1 and 2 shows that the comb PMA gives better fuel economy compared to a linear dispersant PMA or an OCP viscosity modifier. Replacing the sulfonate with a salicylate detergent also resulted in lower fuel economy values, as shown by comparative example 3. Furthermore, a combination of sulfonate detergent and comb PMA in the absence of any additional FMs outperforms comparative example 4, which contains boron-based friction modifiers. It was also

demonstrated that the combination of comb PMA and sulfonate without added FMs (Example 2 vs Comparative Example 6) is effective in a higher viscosity formulation.

[0087] It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments. For example, the functions described above and implemented for operating are for illustration purposes only. Other arrangements and methods may be implemented by those skilled in the art without departing from the scope and spirit of this application. Moreover, those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

CLAIMS

1. A lubricating oil composition for an internal combustion engine, comprising:
 - a) a major amount of oil of lubricating viscosity;
 - b) an alkaline earth metal sulfonate detergent providing 1200-2200ppm of metal to the lubricating oil composition;
 - c) a comb-shaped polymethacrylate viscosity modifier having a PSSI of less than 15;wherein the lubricating oil composition is an 0W-8, an 0W-12, an 0W-16, or an 0W-20 SAE viscosity grade; and
wherein the lubricating oil composition is substantially free of a friction modifier.
2. The lubricating oil composition of claim 1 wherein the lubricating oil composition has a viscosity index of greater than 200.
3. The lubricating oil composition of claim 1 wherein the composition comprises less than 50 ppm of a friction modifier.
4. The lubricating oil composition of claim 1 wherein the composition comprises less than 25 ppm of a friction modifier.
5. The lubricating oil composition of claim 1 wherein the composition comprises 0 ppm of a friction modifier.
6. The lubricating oil composition of claim 1 wherein the composition exhibits a fuel economy improvement (FEI) of at least about 1%.
7. The lubricating oil composition of claim 1 wherein the composition exhibits a fuel economy improvement (FEI) of at least about 2%.
8. The lubricating oil composition of claim 1 wherein the lubricating oil composition is an 0W-8 SAE viscosity grade.
9. The lubricating oil composition of claim 1 wherein the lubricating oil composition is an 0W-12 SAE viscosity grade.

10. The lubricating oil composition of claim 1 wherein the lubricating oil composition is an 0W-16 SAE viscosity grade.
11. The lubricating oil composition of claim 1 wherein the lubricating oil composition is an 0W-20 SAE viscosity grade.
12. The lubricating oil composition of claim 1 wherein the alkaline earth metal sulfonate detergent is a magnesium sulfonate detergent, a calcium sulfonate detergent, or a mixture thereof.
13. A method for improving fuel economy in an internal combustion engine comprising lubricating said engine with a lubricating oil composition comprising:
 - a) a major amount of oil of lubricating viscosity;
 - b) an alkaline earth metal sulfonate detergent providing 1200-2200ppm of metal to the lubricating oil composition;
 - c) a comb-shaped polymethacrylate viscosity modifier having a PSSI of less than 15;wherein the lubricating oil composition is an 0W-8, an 0W-12, an 0W-16, or an 0W-20 SAE viscosity grade; and
wherein the lubricating oil composition is substantially free of a friction modifier.
14. The method of claim 13 wherein the lubricating oil composition has a viscosity index of greater than 200.
15. The method of claim 13 wherein the composition comprises less than 50 ppm of a friction modifier.
16. The method of claim 13 wherein the composition comprises less than 25 ppm of friction modifier.
17. The method of claim 13 wherein the composition comprises 0 ppm of a friction modifier.

18. The method of claim 13 wherein the composition exhibits a fuel economy improvement (FEI) of at least about 1%.
19. The method of claim 13 wherein the composition exhibits a fuel economy improvement (FEI) of at least about 2%.
20. The method of claim 13 wherein the lubricating oil composition is an 0W-8 SAE viscosity grade.
21. The method of claim 13 wherein the lubricating oil composition is an 0W-12 SAE viscosity grade.
22. The method of claim 13 wherein the lubricating oil composition is an 0W-16 SAE viscosity grade.
23. The method of claim 13 wherein the lubricating oil composition is an 0W-20 SAE viscosity grade.
24. The method of claim 13 wherein the alkaline earth metal sulfonate detergent is a magnesium sulfonate detergent, a calcium sulfonate detergent, or a mixture thereof.