

MARINE DIESEL ENGINE LUBRICATING OIL COMPOSITIONS

TECHNICAL FIELD

[0001] This disclosure relates to lubricating oil compositions and more specifically, to the use of light neutral oils and olefin copolymer thickeners in marine lubricating oil compositions.

BACKGROUND

[0002] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0003] Marine diesel internal combustion engines may generally be classified as low-speed, medium-speed, or high-speed engines. Low-speed diesel engines are unique in size and method of operation. These engines are quite large and typically operate in the range of about 60 to 200 revolutions per minute (rpm). A low-speed diesel engine operates on the two-stroke cycle and is typically a direct-coupled and direct-reversing engine of “crosshead” construction, with a diaphragm and one or more stuffing boxes separating the power cylinders from the crankcase to prevent combustion products from entering the crankcase and mixing with the crankcase oil. Marine two-stroke diesel cylinder lubricants must meet performance demands in order to comply with severe operating conditions required for more modern larger bore engines which are run at significantly varying outputs, loads and temperatures of the cylinder liner. The complete separation of the crankcase from the combustion zone has led persons skilled in the art to lubricate the combustion chamber and the crankcase with different lubricating oils, which are referred to as a cylinder lubricant and a system oil, respectively. Marine cylinder lubricants and system oils are subject to their own unique requirements.

[0004] In two-stroke crosshead engines, the cylinders are lubricated on a total loss basis with the cylinder oil being injected separately on each cylinder, by means of lubricators

positioned around the cylinder liner. Cylinder lubricant is not recirculated and is combusted along with the fuel. The cylinder lubricant needs to provide a strong film between the cylinder liner and the piston rings for sufficient lubrication of the cylinder walls to prevent scuffing, be thermally stable in order that the lubricant does not form deposits on the hot surfaces of the piston and the piston rings, and be able to neutralize sulfur-based acidic products of combustion. In contrast to a cylinder lubricant, system oil is not exposed to the combustion chamber where fuels are being combusted and is formulated to last as long as possible to maximize the lifetime of the oil.

[0005] Medium-speed engines typically operate in the range of about 250 to 1100 rpm and operate on the four-stroke cycle. These engines are typically of the trunk piston design. In trunk piston engines, a single lubricating oil is employed for lubrication of all areas of the engine, as opposed to the crosshead engines. A trunk piston engine oil therefore has unique requirements. Key lubricating oil performance parameters for operating trunk piston engines include deposit control of the piston cooling gallery and piston ring pack, oxidation and viscosity increase control, demulsibility performance and sludge control. For marine residual fuels operation, these performance parameters are almost exclusively driven by asphaltenes contamination from marine residual fuels.

[0006] Recent health and environmental concerns have led to regulations mandating the use of lower sulfur fuels for the operation of marine diesel engines. As a result, manufacturers are now designing marine diesel engines for use with a variety of fuels including non-residual gaseous fuels (e.g., compressed or liquefied natural gas), high quality distillate fuel, to poorer quality intermediate or heavy fuel such as marine residual fuel with generally higher sulfur and higher asphaltene content. For non-residual fuel operation, the fuel contains no significant asphaltenes present in the fuels and contains much lower sulfur levels. When the lower sulfur fuel is combusted, less acid is formed in the combustion chamber.

[0007] One of the primary features that lubricants have that help in protecting marine diesel engines is the lubricating oil film “thickness,” i.e., viscosity. Lubricants for the lubrication of marine diesel internal combustion engines have high viscosity industry requirements due to low operating speeds and high loads, and are typically high viscosity monograde (i.e., one which exhibits little or no viscosity index improvement properties) lubricants of the SAE 30, SAE 40, SAE 50 or SAE 60 viscosity grade. Because hydrocracking results in a viscosity loss of the base stocks, marine oils generally cannot be

formulated solely with hydrocracked base stocks. To achieve the appropriate lubricating oil film thickness, conventional marine formulations typically include a majority amount of heavy neutral oils and/or high viscosity bright stock in marine lubricants, bright stock being a high viscosity base oil that is highly refined and dewaxed and that is produced from residual stocks or bottoms.

[0008] However, the reliance on bright stock is not always desirable because of the presence of oxidatively unstable aromatics. In addition, the availability of bright stock is diminishing, resulting in high volume uses such as those for marine engines requiring alternative solutions to impart the desired viscometrics in lubricants. In view of changing severity increases that comes with design changes to modern marine engines, changing mandates relating to fuel quality, along with declining bright stock capacity, there is continuing need for improved marine diesel lubricating oil formulating technology which provides improved performance while achieving the high viscosities necessary for marine lubricants.

SUMMARY

[0009] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0010] In general, in one aspect, the disclosure relates to a marine diesel engine lubricating oil composition that includes (a) at least 40 wt. % of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of from 4.0 to less than 8.5 mm²/s; and (b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000. The marine diesel lubricating oil composition has a TBN of greater than 30 mg KOH/g and is a monograde lubricating oil composition meeting the specifications for SAE J300 revised January 2015 requirements for a SAE 30, SAE 40, SAE 50 or SAE 60 monograde lubricating oil.

[0011] In another aspect, the present disclosure relates to a method of thickening a lubricating oil composition in a marine diesel internal combustion engine. The method includes adding to said engine a lubricating oil composition which includes: (a) at least 40 wt.

% of an oil of lubricating viscosity having a kinematic viscosity at 100°C. of from 4.0 to less than 8.5 mm²/s; and (b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000. The marine diesel lubricating oil composition has a TBN of greater than 30 mg KOH/g and is a monograde lubricating oil composition meeting the specifications for SAE J300 revised January 2015 requirements for a SAE 30, SAE 40, SAE 50 or SAE 60 monograde lubricating oil.

[0012] In a further aspect, the present disclosure relates to a method of controlling deposit formation in an internal combustion engine. The method includes operating the internal combustion engine with a lubricating oil composition. The lubricating oil composition includes: (a) at least 40 wt. % of an oil of lubricating viscosity having a kinematic viscosity at 100°C. of from 4.0 to less than 8.5 mm²/s; and (b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000. The marine diesel lubricating oil composition has a TBN of greater than 30 mg KOH/g and is a monograde lubricating oil composition meeting the specifications for SAE J300 revised January 2015 requirements for a SAE 30, SAE 40, SAE 50 or SAE 60 monograde lubricating oil.

DETAILED DESCRIPTION

Definitions

[0013] In this specification, the following words and expressions, if and when used, have the meanings ascribed below.

[0014] A “major amount” means greater than 40 wt. % of a composition.

[0015] A “minor amount” means less than 40 wt. % of a composition.

[0016] A “marine residual fuel” refers to a material combustible in large marine engines which has a carbon residue, as defined in International Organization for Standardization (ISO) 10370) of at least 2.5 wt. % (e.g., at least 5 wt. %, or at least 8 wt. %) (relative to the total weight of the fuel), a viscosity at 50 °C or greater than 14.0 cSt, such as the marine residual fuels defined in the International Organization for Standardization specification ISO 8217:2005, “Petroleum products--Fuels (class F)--Specifications of marine fuels,” the contents of which are incorporated herein in their entirety.

[0017] A “residual fuel” refers to a fuel meeting the specification of a residual marine fuel as set forth in the ISO 8217:2010 international standard. A “low sulfur marine

fuel” refers to a fuel meeting the specification of a residual marine fuel as set forth in the ISO 8217:2010 specification that, in addition, has about 1.5 wt. % or less, or even about 0.5% wt. % or less, of sulfur, relative to the total weight of the fuel.

[0018] A “distillate fuel” refers to a fuel meeting the specification of a distillate marine fuel as set forth in the ISO 8217:2010 international standard. A “low sulfur distillate fuel” refers to a fuel meeting the specification of a distillate marine fuel set forth in the ISO 8217:2010 international standard that, in addition, has about 0.1 wt. % or less or even about 0.005 wt. % or less, of sulfur, relative to the total weight of the fuel.

[0019] A “low sulfur fuel” refers having about 1.5 wt. % or less, or even about 1.0 wt. % or less, or even 0.5% wt. % or less, or even 0.1 wt. % or less of sulfur, relative to the total weight of the fuel.

[0020] A “high sulfur fuel” is a fuel having greater than 1.5 wt. % of sulfur, relative to the total weight of the fuel.

[0021] The term “on an actives basis” refers to additive material that is not diluent oil or solvent.

[0022] An “alpha-olefin” as used in this specification and claims refers to an olefin that has a carbon-carbon double bond between the first and second carbon atoms of the longest contiguous chain of carbon atoms. The term “alpha-olefin” includes linear and branched alpha olefins unless expressly stated otherwise. In the case of branched alpha olefins, a branch can be at the 2-position (a vinylidene) and/or the 3-position or higher with respect to the olefin double bond. The term “vinylidene” whenever used in this specification and claims refers to an alpha olefin having a branch at the 2-position with respect to the olefin double bond. Alpha-olefins are almost always mixtures of isomers and often also mixtures of compounds with a range of carbon numbers. Low molecular weight alpha olefins, such as the C₆, C₈, C₁₀, C₁₂ and C₁₄ alpha olefins, are almost exclusively 1-olefins. Higher molecular weight olefin cuts such as C₁₆-C₁₈ or C₂₀-C₂₄ have increasing proportions of the double bond isomerized to an internal or vinylidene position

[0023] A “normal alpha olefin” (NAO) refers to a linear aliphatic mono-olefin having a carbon-carbon double bond between the first and second carbon atoms. It is noted that “normal alpha olefin” is not synonymous with “linear alpha olefin” as the term “linear alpha olefin” can include linear olefinic compounds having a double bond between the first and second carbon atoms.

[0024] “Isomerized olefins” or “isomerized normal alpha-olefins” refers to olefins obtained by isomerizing olefins. Generally isomerized olefins have double bonds in different positions than the starting olefins from which they are derived, and may also have different characteristics.

[0025] “Isomerization level (I)” refers to isomerization level measured by a NMR method. The isomerization level of the olefin was determined by hydrogen-1 (¹H) NMR. The NMR spectra were obtained on a Bruker Ultrashield Plus 400 in chloroform-*d*₁ at 400 MHz using TopSpin 3.2 spectral processing software. The isomerization level represents the relative amount of methyl groups (---CH_3) (chemical shift 0.30-1.01 ppm) attached to the methylene backbone groups ($\text{---CH}_2\text{---}$) (chemical shift 1.01-1.38 ppm) and is defined by Equation (I) $=m/(m+n)$, where *m* is NMR integral for methyl groups with chemical shifts between 0.30±0.03 to 1.01±0.03 ppm, and *n* is NMR integral for methylene groups with chemical shifts between 1.01±0.03 to 1.38±0.10 ppm.

[0026] The term “Total Base Number” or “TBN” or “BN” 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. Where TBN values are introduced herein, it should be understood that they are represented in units of mg KOH/g.

[0027] “Overbased” is used to describe metal detergents in which the ratio of the number of equivalents of the metal moiety to the number of equivalents of the acid moiety is greater than one.

[0028] “Soap” means a neutral detergent compound that contains approximately the stoichiometric amount of metal to achieve the neutralization of the acidic group or groups present in the organic acid used to make the detergent.

[0029] “Metal” refers to alkali metals, alkaline earth metals, or mixtures thereof. When an alkali metal is employed, the alkali metal is lithium, sodium or potassium. When an alkaline earth metal is employed, the alkaline earth metal can be selected from the group consisting of calcium, barium, magnesium and strontium. Calcium and magnesium are preferred.

[0030] “Weight percent” (wt. %), unless expressly stated otherwise, means the percentage that the recited component(s), compounds(s) or substituent(s) represents of the total weight of the entire composition. All percentages reported are weight % on an active ingredient basis (i.e., without regard to carrier or diluent oil) unless otherwise stated. The diluent oil for the lubricating oil additives can be any suitable base oil (e.g., a Group I base oil, a Group II base oil, a Group III base oil, a Group IV base oil, a Group V base oil, or a mixture thereof). Weight percentages that represent the combination of ingredients and carrier or diluent oil are referred to as weight percentages “as received.”

[0031] The term “sulfated ash content” refers to the amount of metal-containing additives (e.g., calcium, magnesium, molybdenum, zinc) in a lubricating oil composition and is typically measured according to ASTM D874, which is incorporated herein by reference.

Lubricating Oil Composition

[0032] It has been surprisingly found that the substitution (e.g., complete substitution) of heavy neutral base oil and bright stock with the combination of lighter neutral base stocks and olefin copolymer thickener in marine lubricants, provides a lubricating oil composition which exhibits improved resistance to deposit formation and oxidative stability in engines operating under a variety of load conditions, such as high load conditions while achieving the appropriate lubricating oil viscosity.

[0033] The lubricating oil composition of the present disclosure, in certain embodiments, is a marine diesel engine lubricating oil. In such embodiments, the lubricating oil composition includes (a) at least 40 wt. % of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of from 4.0 mm²/s to less than 8.5 mm²/s; and (b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000; wherein the lubricating oil composition is a monograde lubricating oil composition meeting specifications for SAE J300 revised January 2015 requirements for a, 30, 40, 50, or 60 monograde engine oil, and has a TBN of greater than 30 mg KOH/g, as determined by ASTM D2896. The kinematic viscosity of the oil of lubricating viscosity may correspond to the viscosity of a light neutral oil.

[0034] The lubricating oil composition may be a monograde lubricating oil composition meeting specifications for SAE J300 revised January 2015 requirements for a 30, 40, 50, or 60 monograde engine oil. A SAE 30 oil has a kinematic viscosity at 100 °C of

9.3 to <12.5 mm²/s. A SAE 40 oil has a kinematic viscosity at 100 °C of 12.5 to <16.3 mm²/s. A SAE 50 oil has a kinematic viscosity at 100 °C of 16.3 to <21.9 mm²/s. A SAE 60 oil has a kinematic viscosity at 100 °C of 21.9 to <26.1 mm²/s.

[0035] In some embodiments, the lubricating oil composition is suitable for use as a marine cylinder lubricant (MCL). Marine cylinder lubricants of the present disclosure are made to the SAE 30, SAE 40, SAE 50 or SAE 60 monograde specification to provide a sufficiently thick lubricant film at the high temperatures on the cylinder liner wall.

[0036] Aside from providing a sufficient degree of lubricity, one of the primary functions of the marine cylinder lubricant is to neutralize sulfur-based acidic components of sulfur-containing fuel combusted. This neutralization has typically been accomplished by the inclusion of basic species such as overbased metallic detergents. An oil's neutralization capacity is characterized by its basicity and is measured by its Total Base Number (TBN). Typically, sulfur-containing fuels for operation of marine diesel engines create the need for marine cylinder lubricants with high detergency and neutralizing capability even though the oils are exposed to thermal and other stresses only for short periods of time.

[0037] To allow for sufficient neutralization and detergency, marine diesel cylinder lubricants of the present disclosure have a TBN of at least 30 mg KOH/g. By way of example, the TBN may range from greater than 30 to 200 mg KOH/g, or from greater than 30 to 150 mg KOH/g, or from greater than 30 to 120 mg KOH/g, from greater than 30 to 100 mg KOH/g, from greater than 30 to 80 mg KOH/g, from 60 to 200 mg KOH/g, from 60 to 150 mg KOH/g, from 60 to 120 mg KOH/g, from 60 to 100 mg KOH/g, from 60 to 80 mg KOH/g, from 80 to 200 mg KOH/g, from 80 to 150 mg KOH/g, from 80 to 120 mg KOH/g, from 120 to 200 mg KOH/g, or from 120 to 150 mg KOH/g. In certain embodiments, the TBN ranges from 40 to 70 mg KOH/g.

[0038] In some embodiments, the present lubricating oil composition is suitable for use as a marine trunk piston engine oil (TPEO). Marine TPEO lubricants of the present disclosure are made to the SAE 30 or SAE 40 monograde specification. Such marine TPEO lubricants have a TBN ranging from greater than 30 to 80 mg KOH/g (e.g., from 35 to 75 mg KOH/g, from 40 to 70 mg KOH/g).

[0039] In certain embodiments, the lubricating oil compositions of this disclosure have a sulfated ash content of at least 1.50 wt. % as determined by ASTM D 874. For example, the lubricating oil compositions of this disclosure may have a level of sulfated ash

of from 1.5 to 27 wt. % as determined by ASTM D 874. By way of further example, the lubricating oil compositions of this disclosure may have a sulfated ash content of from 2.0 to 25.0 wt. %, 2.5 to 25.0 wt. %, 3.0 to 25.0 wt. %, or 5.0 to 25.0 wt. % as determined by ASTM D 874.

Oil of Lubricating Viscosity

[0040] The lubricating oil composition of the present disclosure has at least 40 wt% of an oil of lubricating viscosity, such as at least 50 wt% (e.g., at least 60 wt. %, at least 70 wt. %, at least 80 wt. %, or at least 90 wt. %), based on the total weight of the composition. For example, the lubricating oil composition of the present disclosure may include between 40 wt% and 95 wt%, between 50 wt% and 90 wt%, between 55 wt% and 85 wt% of the oil of lubricating viscosity. The oil of lubricating viscosity may also be referred to as a base oil.

[0041] In accordance with certain embodiments of this disclosure, the oil of lubricating viscosity has a kinematic viscosity at 100 °C from 4.0 mm²/s to less than 8.5 mm²/s. For example, the oil of lubricating viscosity may have a kinematic viscosity at 100 °C from 4.0 mm²/s to 8 mm²/s, or 4.5 mm²/s to 8 mm²/s, or 5.0 mm²/s to 7.5 mm²/s.

[0042] The oil of lubricating viscosity of the present disclosure may include only one base oil component or may include a mixture of two or more base oil components to achieve the kinematic viscosity noted above. The oil of lubricating viscosity may be selected from any of the base oils in Groups I-V as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines (API 1509). The five base oil groups are summarized in Table 1:

TABLE 1

Group	Saturates ⁽¹⁾	Sulfur ⁽²⁾	Viscosity Index ⁽³⁾	
I	<90% and/or	>0.03% and	≥80 to <120	
II	≥90% and	≤0.03% and	≥80 to <120	
III	≥90% and	≤0.03% and	≥120	
IV				Polyalphaolefins (PAO)
V				All other base stocks not included in Groups I, II, III or IV

⁽¹⁾ ASTM D2007

⁽²⁾ ASTM D2270

⁽³⁾ ASTM D3120, ASTM D4294, or ASTM D4297

[0043] Groups I, II, and III are mineral oil process stocks. Group IV base oils contain true synthetic molecular species, which are produced by polymerization of olefinically unsaturated hydrocarbons. Many Group V base oils are also true synthetic products and may include diesters, polyol esters, polyalkylene glycols, alkylated aromatics, polyphosphate esters, polyvinyl ethers, and/or polyphenyl ethers, and the like, but may also be naturally occurring oils, such as vegetable oils. It should be noted that although Group III base oils are derived from mineral oil, the rigorous processing that these fluids undergo causes their physical properties to be very similar to some true synthetics, such as PAOs. Therefore, oils derived from Group III base oils may be referred to as synthetic fluids in the industry.

[0044] The base oil used in the disclosed lubricating oil composition may be a mineral oil, animal oil, vegetable oil, synthetic oil, or mixtures thereof. Suitable oils may be derived from hydrocracking, hydrogenation, hydrofinishing, unrefined, refined, and re-refined oils, and mixtures thereof.

[0045] Unrefined oils are those derived from a natural, mineral, or synthetic source without or with little further purification treatment. Refined oils are similar to the unrefined oils except that they have been treated in one or more purification steps, which may result in the improvement of one or more properties. Examples of suitable purification techniques are solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, and the like. Oils refined to the quality of an edible may or may not be useful. Edible oils may

also be called white oils. In some embodiments, lubricating oil compositions are free of edible or white oils.

[0046] Re-refined oils are also known as reclaimed or reprocessed oils. These oils are obtained similarly to refined oils using the same or similar processes. Often these oils are additionally processed by techniques directed to removal of spent additives and oil breakdown products.

[0047] Mineral oils may include oils obtained by drilling or from plants and animals or any mixtures thereof. Such oils may include castor oil, lard oil, olive oil, peanut oil, corn oil, soybean oil, and linseed oil, as well as mineral lubricating oils, such as liquid petroleum oils and solvent-treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types. Such oils may be partially or fully hydrogenated, if desired. Oils derived from coal or shale may also be useful.

[0048] Useful synthetic lubricating oils may include hydrocarbon oils such as polymerized, oligomerized, or interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene/isobutylene copolymers); poly(1-hexenes), poly(1-octenes), trimers or oligomers of 1-decene, e.g., poly(1-decenes), such materials being often referred to as α -olefins, and mixtures thereof; alkylbenzenes (e.g. dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di-(2-ethylhexyl)-benzenes); polyphenyls (e.g., biphenyls, terphenyls, alkylated polyphenyls); diphenyl alkanes, alkylated diphenyl alkanes, alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs and homologs thereof or mixtures thereof. Polyalphaolefins are typically hydrogenated materials.

[0049] Other synthetic lubricating oils include polyol esters, diesters, liquid esters of phosphorus-containing acids (e.g., tricresyl phosphate, trioctyl phosphate, and the diethyl ester of decane phosphonic acid), or polymeric tetrahydrofurans. Synthetic oils may be produced by Fischer-Tropsch reactions and typically may be hydroisomerized Fischer-Tropsch hydrocarbons or waxes. In one embodiment oils may be prepared by a Fischer-Tropsch gas-to-liquid synthetic procedure as well as other gas-to-liquid oils.

[0050] Base oils for use in the formulated lubricating oils useful in the present disclosure are any of the variety of oils corresponding to API Group I, Group II, Group III, Group IV, and Group V oils and mixtures thereof. In one embodiment, the base oil is a Group II base oil or a blend of two or more different base oils. In another embodiment, the base oil is a Group I base oil or a blend of two or more different Group I base oils. Suitable

Group I base oils include any light overhead cuts from a vacuum distillation column, such as, for example, any Light Neutral, Medium Neutral, and Heavy Neutral base stocks.

[0051] The base oil may also include residual base stocks or bottoms fractions such as bright stock. Bright stock is a high viscosity base oil which has been conventionally produced from residual stocks or bottoms and has been highly refined and dewaxed. Bright stock can have a kinematic viscosity at 40 °C of greater than 180 mm²/s (e.g., greater than 250 mm²/s, or even in a range of 500 to 1100 mm²/s). In certain embodiments, the lubricating oil composition does not contain bright stock.

Thickener

[0052] In accordance with present embodiments, to obtain a finished lubricating oil composition having a desired viscosity grade, a thickener may be added to the lubricating oil composition to increase its viscosity. It has been surprisingly found that substitution of heavy neutral base oil and bright stock with the combination of lighter neutral base stocks and olefin copolymer thickener in marine lubricants, provides a lubricating oil composition which exhibits improved resistance to deposit formation and oxidative stability in engines operating under high load conditions while achieving the appropriate lubricating oil viscosity.

[0053] In accordance with embodiments of this disclosure, suitable thickeners may include olefin copolymers (OCP). Such additives will generally be present, on an actives basis, at 0.1 wt. % or greater, for example at 0.1 to 12 wt. % of the lubricating oil composition. In certain embodiments, the OCP is present, on an actives basis, at 0.2 to 10 wt. %, 0.3 to 9 wt. %, 0.4 to 8 wt. %, or 0.5 to 7 wt. % of the lubricating oil composition. In still further embodiments, the OCP is present, on an actives basis, at 0.5 to 12.0 wt.%, 0.5 to 5 wt. %, or 1 to 2 wt. % of the lubricating oil composition. In still further embodiments, the OCP is present, on an actives basis, at 1.0 wt. % or greater, for example at 1.0 to 12.0 wt. %, 1.0 wt. % to 5 wt. %, 1.3 wt. % to 4.5 wt. %, 1.5 wt. % to 4.0 wt. %, 2.0 to 12.0 wt.%, or 2.0 wt. % to 3.5 wt. % of the lubricating oil composition. In certain embodiments, the OCP is the only viscosity modifier or thickener present in the lubricating oil composition.

[0054] In certain embodiments, the olefin copolymers are copolymers based on ethylene units and units of an alpha olefin (e.g., a normal alpha olefin, an isomerized alpha olefin), such as ethylene-propylene copolymer compositions. Other alpha olefins suitable in place of propylene, or in combination with ethylene and propylene to form a terpolymer or

tetrapolymer, for example, include: 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene; and branched chain alpha-olefins such as 4-methyl-1-pentene, 4-methyl-1-hexene, 4-methyl pentene-1, 4,4-dimethyl-1-pentene, 6-methylheptene-1, and mixtures thereof.

[0055] The olefin copolymer according to certain embodiments of the invention advantageously has a number average molecular weight of between 30,000 and 120,000 g/mol, preferably between 40,000 and 120,000 g/mol, more preferably between 45,000 and 115,000 g/mol. In some embodiments, such a molecular weight may balance useful thickening with stability of the formulation under stress. The molecular weight, in combination with the above-referenced amounts, may provide a viscosity appropriate for marine cylinder and TPEO lubricant compositions.

[0056] The shear stability index (SSI) of the olefin copolymer, i.e., its resistance to mechanical degradation under shearing stress, ranges from 5-50. In certain embodiments, the SSI ranges from 15-50, such as 24-50, or from 24-40.

[0057] The olefin copolymer according to certain embodiments of the invention advantageously has a content of ethylene units ranging from 30% to 80% by weight relative to the weight of olefin copolymer, preferably from 30% to 75%, more preferably 49% to 72% by weight. The olefin copolymer according to the invention also advantageously has a content of ethylene units, ranging from 40% to 90% by mole, relative to the number of moles of olefin copolymer, preferably from 40% to 80%, more preferably from 50% to 80%.

[0058] The olefin copolymer according to certain embodiments of the invention may be a bimodal ethylene copolymer composition having a first ethylene copolymer fraction having relatively lower ethylene content; and a second ethylene copolymer fraction having relatively higher ethylene content. In one embodiment, the polymerization processes used to produce the olefin copolymer may include copolymerizing two or more alpha olefin monomers (one of which is preferably ethylene; the other in some aspects may be a C₃ - C₁₂ alpha olefin, such as propylene) in the presence of one or more metallocene catalysts. The olefin copolymer used in certain embodiments may include one or more olefin copolymers set forth in US20130203640, the disclosure of which is incorporated herein by reference in its entirety.

[0059] In certain of these embodiments, the olefin copolymer compositions of the present disclosure may include (a) a first ethylene-alpha-olefin copolymer and (b) a second

ethylene-alpha-olefin copolymer. As an example, the first ethylene-alpha-olefin copolymer (a) has an ethylene content from about 60 to about 80 wt % and can be referred to herein as a “semi-crystalline” ethylene-alpha-olefin copolymer. More typically, the ethylene content of the first ethylene-alpha-olefin copolymer is from about 63 to about 77 wt %, and even more typically, the ethylene content of the first ethylene-alpha-olefin copolymer is from about 65 to about 75 wt %. The second ethylene-alpha-olefin copolymer (b) has an ethylene content of less than about 60 wt %, more typically less than about 55 wt % and even more typically about 42 to about 54 wt % and is a lower crystalline ethylene-alpha-olefin copolymer than is the first ethylene-alpha-olefin copolymer (a) and can be referred to herein as an “amorphous” ethylene-alpha-olefin copolymer.

[0060] The first ethylene-alpha-olefin copolymer (a) can have a Melt Flow Rate Ratio (MFRR), defined as the ratio of the MFR measured at 230 °C/21.6 kg and at 230 °C/2.16 kg, of >30, and more typically up to about 55, even more typically about 33 to about 45, preferably >34, and more preferably about 34 to about 45 and more preferably about 35 to about 43. The first ethylene-alpha-olefin copolymer (a), when the MFR condition is also observed, has a MFR that is at least about 1.5 g/10 min., in another embodiment the MFR is at least about 1.6 g/10 min. A more typical range of the MFR is about 1.5 g/10 min. to about 6.5 g/10 min., and an even more typical range is about 2.5 g/10 min. to about 5.5 g/10 min. The MFR is measured by ASTM D 1238 condition L (230° C/2.16 kg). In one embodiment, the first ethylene-alpha-olefin copolymer (a) has a MFRR >30 and a MFR of at least about 1.5 g/10 min. More preferably, the first ethylene-alpha-olefin copolymer (a) has a MFRR >34 and a MFR of at least about 1.6 g/10 min.

[0061] In one embodiment, the olefin copolymer compositions contain about 30 wt % to about 70 wt % of the first ethylene-alpha-olefin copolymer (a) and about 70 wt % to about 30 wt % of the second ethylene-alpha-olefin copolymer (b) based upon the total amount of (a) and (b) in the composition. In another embodiment, the olefin copolymer compositions contain about 40 wt % to about 60 wt % of the first ethylene-alpha-olefin copolymer (a) and about 60 wt % to about 40 wt % of the second ethylene-alpha-olefin copolymer (b) based upon the total amount of (a) and (b) in the composition. In a particular embodiment, the olefin copolymer composition contains about 50 to about 54 wt % of the first ethylene-alpha-olefin copolymer (a) and about 46 to about 50 wt % of the second ethylene-alpha-olefin copolymer (b) based upon the total amount of (a) and (b) in the composition.

[0062] The weight average molecular weight of the first ethylene-alpha-olefin copolymer in one embodiment is about 60,000 to about 120,000. In another embodiment, the weight average molecular weight of the first ethylene-alpha-olefin copolymer is about 70,000 to about 110,000. The weight average molecular weight of the second ethylene-alpha-olefin copolymer in one embodiment is about 60,000 to about 120,000. In another embodiment, the weight average molecular weight of the second ethylene-alpha-olefin copolymer is about 70,000 to about 110,000.

[0063] The weight average molecular weight of the composition of the first ethylene-alpha-olefin copolymer and second ethylene-alpha-olefin copolymer in one embodiment is about 60,000 to about 120,000. In another embodiment, the weight average molecular weight of the composition of the first ethylene-alpha-olefin copolymer and second ethylene-alpha-olefin copolymer is about 70,000 to about 110,000. In a still further embodiment, the weight average molecular weight of the composition of the first ethylene-alpha-olefin copolymer and second ethylene-alpha-olefin copolymer is about 80,000 to about 100,000. The molecular weight distribution of each of the ethylene-alpha-olefin copolymers may be less than about 2.5, and more typically about 2.1 to about 2.4. The polymer distribution as determined by GPC of each of the ethylene-alpha-olefin copolymers is typically unimodal.

Other Performance Additives

[0064] The lubricating oil compositions of the present disclosure may contain one or more performance additives that can impart or improve any desirable property of the lubricating oil composition. Any additive known to those of skill in the art may be used in the lubricating oil composition disclosed herein. Some suitable additives have been described by R. M. Mortier et al. "Chemistry and Technology of Lubricants," 3rd Edition, Springer (2010) and L. R. Rudnik "Lubricant Additives: Chemistry and Applications," Second Edition, CRC Press (2009).

[0065] In general, the concentration of each of the additives in the lubricating oil composition, when used, may range from 0.001 to 10 wt. % (e.g., 0.01 to 5 wt. %, or 0.05 to 2.5 wt. %) of the lubricating oil composition. Including diluent oil, each of additives in the lubricating oil composition may range from 0.5 to 45 wt. % (e.g., 1.0 to 45 wt. %, 5.0 to 40 wt. %, 10 to 35 wt. %, 20 to 32 wt. %, or 25 to 30 wt. %) of the lubricating oil composition. Further, the total amount of additives in the lubricating oil composition may range from 0.001

to 20 wt. % (e.g., 0.01 to 15 wt. % or 0.1 to 10 wt. %) of the lubricating oil composition. Including diluent oil, the total amount of additives in the lubricating oil composition may range from 0.5 to 78 wt. % (e.g., 1.0 to 78 wt. %, 5.0 to 78 wt. %, 10 to 78 wt. %, 20 to 78 wt. %, 30 to 78 wt. %, or 45 to 78 wt. %) of the lubricating oil composition.

[0066] As examples, the present lubricating oil composition may contain one or more lubricating oil performance additives including detergents, dispersants, antiwear agents, antioxidants, friction modifiers, corrosion inhibitors, rust inhibitors, demulsifiers, foam inhibitors, viscosity modifiers, pour point depressants, non-ionic surfactants, thickeners, and the like. Some are discussed in further detail below.

Detergents

[0067] The lubricating oil compositions of the present disclosure may include one or more detergents. A detergent is an additive that reduces formation of piston deposits, for example high-temperature varnish and lacquer deposits in engines. The detergent normally has acid-neutralizing properties and is capable of keeping finely-divided solids in suspension. Most detergents are metal salts of acidic organic compounds.

[0068] Metal-containing or ash-forming detergents function as both detergents to reduce or remove deposits and as acid neutralizers or rust inhibitors, thereby reducing wear and corrosion and extending engine life. Detergents generally include a polar head with a long hydrophobic tail. The polar head includes a metal salt of an acidic organic compound.

[0069] In the art, detergents are generally referred to as neutral or overbased. Detergents which contain a substantially stoichiometric amount of the metal salt are usually described as normal or neutral detergents. In embodiments where a large amount of a metal base is incorporated in the detergent by reacting excess metal compound (e.g., an oxide or hydroxide) with an acidic gas (e.g., carbon dioxide), the detergents are referred to as being overbased.

[0070] Overbased metal detergents are generally produced by carbonating (with CO₂) a mixture of hydrocarbons, detergent acid (for example sulfonic acid or carboxylate), metal oxide or hydroxides (for example calcium oxide or calcium hydroxide) and promoters such as xylene, methanol, and/or 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.

[0071] Overbased detergents may be further characterized as low overbased, medium overbased, or high overbased. Low overbased detergents may be, for example, an overbased salt having a TBN below 100. In one embodiment, the TBN of a low overbased salt may be from about 5 to about 80. In another embodiment, the TBN of a low overbased salt may be from about 10 to about 80. In yet another embodiment, the TBN of a low overbased salt may be from about 10 to about 50.

[0072] Medium overbased detergents, may be, for example, an overbased salt having a TBN from about 100 to about 250. In one embodiment, the TBN of a medium overbased salt may be from about 100 to about 200. In another embodiment, the TBN of a medium overbased salt may be from about 125 to about 175.

[0073] High overbased detergents may be, for example, an overbased salt having a TBN above 250. In one embodiment, the TBN of a high overbased salt may be from about 250 to about 800.

[0074] Compounds that may be used in the detergents 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., 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.

[0075] In one embodiment, the detergent can be one or more alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid and is a carboxylate or a salicylate. Suitable hydroxyaromatic compounds include mononuclear monohydroxy and polyhydroxy aromatic hydrocarbons having 1 to 4, and preferably 1 to 3, hydroxyl groups.

[0076] Suitable hydroxyaromatic compounds include phenol, catechol, resorcinol, hydroquinone, pyrogallol, cresol, and the like. In certain embodiments the preferred hydroxyaromatic compound is phenol.

[0077] The alkyl substituted moiety of the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid may be derived from an alpha olefin having from 10 to 80 carbon atoms. The olefins employed may be linear, isomerized linear, branched or partially branched linear. The olefin may be a mixture of linear olefins, a mixture of isomerized linear olefins, a mixture of branched olefins, a mixture of partially branched linear or a mixture of any of the foregoing.

[0078] In some embodiments, the mixture of linear olefins is a mixture of normal alpha olefins selected from olefins having from 10 to 40 carbon atoms per molecule. In one embodiment, the normal alpha olefins are isomerized using at least one of a solid or liquid catalyst.

[0079] In some embodiments, at least about 75 mole % (e.g., at least about 80 mole %, at least about 85 mole %, at least about 90 mole %, at least about 95 mole %, or at least about 99 mole %) of the alkyl groups contained within the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid such as the alkyl groups of an alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid detergent are a C₂₀ or higher alkyl substituent. In certain of these embodiments, the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is an alkali or alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid that is derived from an alkyl-substituted hydroxybenzoic acid in which the alkyl groups are the residue of normal alpha-olefins containing at least 75 mole % C₂₀ to C₂₈ normal alpha-olefins. In another embodiment, at least about 50 mole % (e.g., at least 60 mole %, at least 70 mole %, at least 80 mole %, at least 85 mole %, at least 90 mole %, at least 95 mole %, or at least 99 mole %) of the alkyl groups of an alkali or alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid are C₂₀ to C₂₄ alkyl substituents.

[0080] In another embodiment, at least about 50 mole % (e.g., at least 60 mole %, at least 70 mole %, at least 80 mole %, at least 85 mole %, at least 90 mole %, at least 95 mole %, or at least 99 mole %) of the alkyl groups of an alkali or alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid are C₁₄ to C₁₈ alkyl substituents. In another embodiment, the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is derived from an alkyl group with isomerized C₁₀-C₄₀ normal alpha olefins, isomerized C₂₀-C₂₈ normal alpha olefins, or preferably isomerized C₂₀-C₂₄ normal alpha olefins. In one embodiment, the isomerized normal alpha olefins have an isomerization level of the alpha olefin between from about 0.1 to about 0.4. In another embodiment, the alkyl group is derived from at least two alkyl phenols. The alkyl group on at least one of the at least two alkyl phenols is derived from an isomerized alpha olefin. The alkyl group on the second alkyl phenol may be derived from branched or partially branched olefins, highly isomerized olefins or mixtures thereof.

[0081] The alkyl substituted moiety of the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid may be derived from cashew nut shell

liquid (CNSL) or hydrogenated distilled CNSL. Distilled CNSL is a mixture of biodegradable meta-hydrocarbyl substituted phenols, where the hydrocarbyl group is linear and unsaturated, including cardanol. Catalytic hydrogenation of distilled CNSL gives rise to a mixture of meta-hydrocarbyl substituted phenols predominantly rich in 3-pentadecylphenol.

[0082] The alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid may be a mixture of ortho and para isomers. In one embodiment, the alkyl-substituted hydroxyaromatic carboxylic acid may contain 1 to 99% ortho isomer and 99 to 1% para isomer. In another embodiment, the alkyl-substituted hydroxyaromatic carboxylic acid may contain about 5 to 70% ortho and 95 to 30% para isomer.

[0083] The alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid may be neutral or overbased. Generally, an overbased alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is one in which the TBN of the alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid has been increased by a process such as the addition of a base source (e.g., lime) and an acidic overbasing compound (e.g., carbon dioxide).

[0084] As noted, certain embodiments of lubricating oil formulations may utilize one or more sulfonate detergents, either alone or in combination with other detergents. Sulfonates may be prepared from sulfonic acids which may be 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 of alkyl substituted aromatic hydrocarbons which may be sulfonated include those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl or their halogen derivatives. The alkylation may be carried out in the presence of a catalyst with alkylating agents having from 3 to more than 70 carbon atoms. The alkaryl sulfonates usually contain from 9 to 80 or more carbon atoms, preferably from 16 to 60, preferably from 16 to 30, most preferably from 20 to 24 carbon atoms per alkyl substituted aromatic moiety.

[0085] 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.

[0086] Metal salts of phenols and sulfurized phenols (e.g., phenate or sulfurized phenate detergents) are prepared by reaction of the phenol or sulfurized phenol with an

appropriate metal compound such as an oxide or hydroxide. 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 two or more phenols are bridged by sulfur-containing bridges. Additional details regarding the general preparation of sulfurized phenates can be found in, for example, U.S. Pat. Nos. 2,680,096; 3,178,368 and 3,801,507, the contents of which are incorporated herein by reference.

[0087] The sulfur employed for formation of a sulfurized compound may have any allotropic form of sulfur. The sulfur may be present either as molten sulfur or as a solid (e.g., powder or particulate) or as a solid suspension in a compatible hydrocarbon liquid.

[0088] In some embodiments, it is desirable to use calcium hydroxide as the calcium base because of its handling convenience versus, for example, calcium oxide, and also because it affords excellent results. Other calcium bases can also be used, for example, calcium alkoxides.

[0089] Suitable alkylphenols which can be used are those wherein the alkyl substituents contain a sufficient number of carbon atoms to render the resulting alkylphenate (e.g., overbased sulfurized calcium alkylphenate) composition oil-soluble. Oil solubility may be provided by a single long chain alkyl substitute or by a combination of alkyl substituents. Typically, the alkylphenol used in will be a mixture of different alkylphenols, e.g., C₂₀ to C₂₄ alkylphenol. In one embodiment, suitable alkyl phenolic compounds will be derived from isomerized normal alpha olefin alkyl groups having from about 10 to about 40 carbon atoms per molecule, having an isomerization level of the alpha olefin between from about 0.1 to about 0.4. In one embodiment, the isomerized normal alpha olefins have from about 20 to about 24 carbon atoms. In one embodiment, suitable alkyl phenolic compounds will be derived from alkyl groups which are branched olefinic propylene oligomers or mixture thereof having from about 9 to about 80 carbon atoms. In one embodiment, the branched olefinic propylene oligomer or mixtures thereof have from about 9 to about 40 carbon atoms. In one embodiment, the branched olefinic propylene oligomer or mixtures thereof have from about 9 to about 18 carbon atoms. In one embodiment, the branched olefinic propylene oligomer or mixtures thereof have from about 9 to about 12 carbon atoms.

[0090] In one embodiment, suitable alkyl phenolic compounds include distilled cashew nut shell liquid (CNSL) or hydrogenated distilled CNSL. Distilled CNSL is a

mixture of biodegradable meta-hydrocarbyl substituted phenols, where the hydrocarbyl group is linear and unsaturated, including cardanol. Catalytic hydrogenation of distilled CNSL gives rise to a mixture of meta-hydrocarbyl substituted phenols predominantly rich in 3-pentadecylphenol.

[0091] The alkylphenols can be para-alkylphenols, meta-alkylphenols or ortho alkylphenols. In certain embodiments, such as where overbased products are desired, the alkylphenol is preferably predominantly a para alkylphenol with no more than about 45 mole percent of the alkylphenol being ortho alkylphenols; and more preferably no more than about 35 mole percent of the alkylphenol is ortho alkylphenol. Alkyl-hydroxy toluenes or xylenes, and other alkyl phenols having one or more alkyl substituents in addition to at least one long chained alkyl substituent can also be used. In the case of distilled cashew nut shell liquid, the catalytic hydrogenation of distilled CNSL gives rise to a mixture of meta-hydrocarbyl substituted phenols.

[0092] In general, the selection of alkylphenols can be based on the properties desired for the marine diesel engine lubricating oil compositions, notably TBN, and oil solubility. Additional information regarding preparation of suitable alkylphenols can be found, for example, in U.S. Pat. Nos. 5,024,773, 5,320,763; 5,318,710; and 5,320,762, each of which are incorporated herein by reference.

[0093] Generally, the amount of the detergent can be from about 0.001 wt. % to about 50 wt. %, or from about 0.05 wt. % to about 25 wt. %, or from about 0.1 wt. % to about 20 wt. %, or from about 0.01 to 15 wt. % based on the total weight of the marine diesel lubricating oil composition.

[0094] Detergents may also include “hybrid” or “complex” detergents formed with mixed surfactant systems including phenate and/or sulfonate components, e.g., phenate/salicylates, sulfonate/phenates, sulfonate/salicylates, sulfonate/phenate/salicylates, as described for example in US Patents 6,429,178; 6,429,179; 6,153,565. Detergents may also include methylene-bridged polyphenol compositions prepared from the reaction of phenol with formaldehyde, or a reversible polymer thereof, optionally sulfurizing the methylene-bridged intermediate and subsequently reacting the intermediate with an excess of a metal base to produce a methylene bridged polyphenol phenate composition. In one embodiment the methylene bridged polyphenol phenate composition may be further reacted with an

epoxide. In one embodiment the methylene bridged polyphenol phenate composition is not sulfurized.

[0095] Other detergents can be present in any appropriate amount, such as at 0.1 to 45 wt. %, or at 0.5 to 30 wt. % of the lubricating oil composition.

Dispersants

[0096] The lubricating oil compositions of the present disclosure may include one or more dispersants. During engine operation, oil-insoluble oxidation by-products are produced. Dispersants help keep these by-products in solution, thus diminishing their deposition on metal surfaces. Dispersants are often known as ashless-type dispersants because, prior to mixing in a lubricating oil composition, they do not contain ash-forming metals and they do not normally contribute any ash when added to a lubricant. Ashless-type dispersants are characterized by a polar group attached to a relatively high molecular or weight hydrocarbon chain. Typical ashless dispersants include N-substituted long chain alkenyl succinimides. Examples of N-substituted long chain alkenyl succinimides include polyisobutylene succinimide with number average molecular weight of the polyisobutylene substituent in a range of 500 to 5000 Daltons (e.g., 900 to 2500 Daltons). Succinimide dispersants and their preparation are disclosed, for instance in U.S. Patent Nos. 4,234,435 and 7,897,696. Succinimide dispersants are typically an imide formed from a polyamine, typically a poly(ethyleneamine).

[0097] In some embodiments the lubricant composition comprises at least one polyisobutylene succinimide dispersant derived from polyisobutylene with number average molecular weight in the range of 500 to 5000 Daltons (e.g., 900 to 2500 Daltons). The polyisobutylene succinimide may be used alone or in combination with other dispersants.

[0098] The dispersant may also be post-treated by conventional methods by reaction with any of a variety of agents. Among these agents are boron compounds (e.g., boric acid) and cyclic carbonates (ethylene carbonate).

[0099] Another class of dispersants includes Mannich bases. Mannich bases are materials that are formed by the condensation of a higher molecular weight, alkyl substituted phenol, a polyalkylene polyamine, and an aldehyde such as formaldehyde. Mannich bases are described in more detail in U.S. Patent No. 3,634,515.

[0100] Another class of dispersant includes high molecular weight esters, prepared by reaction of a hydrocarbyl acylating agent and a polyhydric aliphatic alcohol such as glycerol,

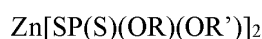
pentaerythritol, or sorbitol. Such materials are described in more detail in U.S. Patent No. 3,381,022.

[0101] Another class of dispersants includes high molecular weight ester amides.

[0102] The dispersant can be present at 0.1 to 15 wt. % of the lubricating oil composition.

Antiwear Agents

[0103] Anti-wear agents reduce friction and excessive wear and are usually based on compounds containing sulfur or phosphorous or both. Noteworthy are dihydrocarbyl dithiophosphate metal salts wherein the metal may be an alkali or alkaline earth metal, or aluminum, lead, tin, molybdenum, manganese, nickel, copper, or zinc. 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 hydrocarbyl radicals containing from 1 to 18 (e.g., 2 to 12) carbon atoms. To obtain oil solubility, the total number of carbon atoms (i.e., R and R') in the dithiophosphoric acid will generally be 5 or greater.

[0104] The antiwear agent can be present at 0.1 to 6 wt. % of the lubricating oil composition.

Antioxidants

[0105] Antioxidants slow the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, or a viscosity increase in the lubricant.

[0106] Useful antioxidants include hindered phenols. Hindered phenol antioxidants often contain a secondary butyl and/or a tertiary butyl group as a sterically hindering group. The phenol group may be further substituted with a hydrocarbyl group (typically linear or branched alkyl) and/or a bridging group linking to a second aromatic group. Examples of hindered phenol antioxidants include 2,6-di-*tert*-butylphenol, 2,6-di-*tert*-butylcresol, 2,4,6-tri-*tert*-butylphenol, 2,6-di-alkyl-phenolic propionic ester derivatives, and bisphenols such as 4,4'-bis(2,6-di-*tert*-butylphenol) and 4,4'-methylene-bis(2,6-di-*tert*-butylphenol).

[0107] Sulfurized alkylphenols and alkali and alkaline earth metal salts thereof are also useful as antioxidants.

[0108] Non-phenolic antioxidants which may be used include aromatic amine antioxidants such as diarylamines and alkylated diarylamines. Particular examples of aromatic amine antioxidants include N-phenyl-2-naphthylamine, 4,4'-dioctyldiphenylamine, butylated/octylated diphenylamine, nonylated diphenylamine, and octylated N-phenyl-2-naphthylamine.

[0109] The antioxidant can be present at 0.01 to 15.0 wt. % of the lubricating oil composition.

Friction Modifiers

[0110] A friction modifier is any material that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material. Suitable friction modifiers may include fatty amines, esters such as borated glycerol esters, fatty phosphites, fatty acid amides, fatty epoxides, borated fatty epoxides, alkoxylated fatty amines, borated alkoxylated fatty amines, metal salts of fatty acids, or fatty imidazolines, and condensation products of carboxylic acids and polyalkylene-polyamines. As used herein, the term "fatty" in relation to friction modifiers means a carbon chain having 10 to 22 carbon atoms, typically a straight carbon chain. Molybdenum compounds are also known as friction modifiers. The friction modifier can be present at 0.01 to 10.0 wt. % of the lubricating oil composition.

Rust Inhibitors

[0111] Rust inhibitors generally protect lubricated metal surfaces against chemical attack by water or other contaminants. Suitable rust inhibitors may include nonionic suitable rust inhibitors include nonionic polyoxyalkylene agents (e.g., polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonylphenyl ether, polyoxyethylene octylphenyl ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monostearate, polyoxyethylene sorbitol monooleate, and polyethylene glycol monooleate); stearic acid and other fatty acids; dicarboxylic acids; metal soaps; fatty acid amine salts; metal salts of heavy sulfonic acid; partial carboxylic acid esters of polyhydric alcohols; phosphoric esters; (short-chain) alkenyl succinic acids, partial esters thereof and nitrogen-containing derivatives thereof; and synthetic alkarylsulfonates (e.g., metal dinonylnaphthalene sulfonates). Such additives can be present at 0.01 to 5 wt. % of the lubricating oil composition.

Demulsifiers

[0112] Demulsifiers promote oil-water separation in lubricating oil compositions exposed to water or steam. Suitable demulsifiers include trialkyl phosphates, and various polymers and copolymers of ethylene glycol, ethylene oxide, propylene oxide, or mixtures thereof. Such additives can be present at 0.01 to 5 wt. % of the lubricating oil composition.

Foam Inhibitors

[0113] Foam inhibitors retard the formation of stable foams. Silicones and organic polymers are typical foam inhibitors. For example, polysiloxanes, such as silicon oil, or polydimethylsiloxane, provide foam inhibiting properties. Further foam inhibitors include copolymers of ethyl acrylate and 2-ethylhexyl acrylate and optionally vinyl acetate. Such additives can be present at 0.001 to 1 wt. % of the lubricating oil composition.

Viscosity Modifiers

[0114] Viscosity modifiers provide lubricants with high and low temperature operability. These additives impart shear stability at elevated temperatures and acceptable viscosity at low temperatures. Suitable viscosity modifier may include polyolefins, olefin copolymers (OCP), ethylene/propylene copolymers, polyisobutenes, hydrogenated styrene-isoprene polymers, styrene/maleic ester copolymers, hydrogenated styrene/butadiene copolymers, hydrogenated isoprene polymers, alpha-olefin maleic anhydride copolymers, polymethacrylates, polyacrylates, polyalkyl styrenes, and hydrogenated alkenyl aryl conjugated diene copolymers. Such additives can be present at 0.1 to 15 wt. % of the lubricating oil composition.

Pour Point Depressants

[0115] Pour point depressants lower the minimum temperature at which a fluid will flow or can be poured. Examples of suitable pour point depressants include polymethacrylates, polyacrylates, polyacrylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty acids and allyl vinyl ethers. Such additives can be present at 0.01 to 1.0 wt. % of the lubricating oil composition.

Non-ionic Surfactants

[0116] Non-ionic surfactants such as alkylphenol may improve asphaltene handling during engine operation. Examples of such materials include alkylphenol having an alkyl

substituent from a straight chain or branched alkyl group having from 9 to 30 carbon atoms. Other examples include alkyl benzenol, alkyl naphthol and alkyl phenol aldehyde condensates where the aldehyde is formaldehyde such that the condensate is a methylene-bridged alkylphenol. Such additives can be present at 0.1 to 20 wt. % of the lubricating oil composition.

Markers

[0117] The lubricating oil compositions of the present invention may contain dyes or marker components, e.g., tracers, which are particularly suitable for marking lubricants to protect brand equity, prevent misidentification and aid in identifying leaks. The most useful types of markers or dyes are ones which may be extracted easily from said marked liquids, measured and/or identified. The many additives and tracers which have been proposed for use or are in current use for marking or tagging lubricants include color and fluorescent dyes (e.g., diazo dyes, anthraquinone dyes, phthalein dyes, and the like), radioactive substances, metal compounds or complexes (e.g., metal organic compounds, metal salts, metal oxides, metal coordination complexes and the like), and a variety of specific compounds which react in combination with selected agents to provide intensely colored derivatives.

[0118] Examples of markers include material selected from the group consisting of: barium sulfate, bismuth trioxide, iodine, iodide, titanium oxide, zirconium oxide, gold, platinum, silver, tantalum, niobium, stainless steel, and combinations thereof. Materials such as certain metallic soaps, metallic soaps of fatty acids, metallic carboxylates, or known metal drying agents supplied as solutions containing metals such as cobalt, lead, magnesium, titanium, zirconium, manganese, rhodium, platinum, aluminum, manganese, calcium, cerium, copper, nickel, vanadium, barium, tungsten, vanadium, and zinc, and mixtures thereof are also useful as lubricant markers. Examples of zirconium containing materials can include zirconium carboxylates such as zirconium 2-ethylhexanoate, zirconium octoate and zirconium salicylate materials.

Use of the Lubricating Oil Composition

[0119] The lubricant compositions may be effective as lubricating oils for compression-ignited internal combustion engines, including marine diesel engines, stationary gas engines, and the like.

[0120] The internal combustion engine may be a 2-stroke or 4-stroke engine.

[0121] In an embodiment, the internal combustion engine is a marine diesel engine. The marine diesel engine may be a medium-speed 4-stroke compression-ignited engine having a speed of 250 to 1100 rpm or a low-speed crosshead 2-stroke compression-ignited engine having a speed of 200 rpm or less (e.g., 60 to 200 rpm).

[0122] The marine diesel engine may be lubricated with a marine diesel cylinder lubricant (typically in a 2-stroke engine), a system oil (typically in a 2-stroke engine), or a crankcase lubricant (typically a 4-stroke engine).

[0123] The term “marine” does not restrict the engines to those used in water-borne vessels; as is understood in the art, it also includes those for other industrial applications such as auxiliary power generation for main propulsion and stationary land-based engines for power generation.

[0124] In some embodiments, the internal combustion engine may be fueled with a residual fuel, a marine residual fuel, a low sulfur marine residual fuel, a marine distillate fuel, a low sulfur marine distillate fuel, or a high sulfur fuel.

[0125] The internal combustion engine can also be operable with a “gaseous fuel” such as a methane-dominated fuel (e.g., natural gas), a biogas, a gasified liquefied gas, or a gasified liquefied natural gas (LNG).

EXAMPLES

[0126] The following illustrative examples are intended to be non-limiting.

[0127] The following components were used in the formulation of the marine lubricating oil compositions of the examples. Generally, the marine lubricating oil compositions of the examples included an oil of lubricating viscosity (a base oil component), a thickener, and an additive package.

[0128] The base oil components used in the formulations of the examples included:

[0129] XOM 150N: ExxonMobil CORE® 150N Group I lubricating oil, kv @100 °C 5.1 mm²/s

[0130] XOM 600N: ExxonMobil CORE® 600N: Group I lubricating oil, kv @100 °C 12.4 mm²/s

[0131] XOM 2500BS: ExxonMobil CORE® 2500BS: Group I lubricating oil, kv @100 °C 30.6 mm²/s

[0132] RLOP 100R: Chevron 100R Group II lubricating oil, kv @100 °C 4.4 mm²/s

[0133] RLOP 220R: Chevron 220 RLOP: Group II lubricating oil, kv@100°C 6.4 mm²/s

[0134] RLOP 600R: Chevron 600R RLOP: Group II lubricating oil, kv @100 °C 12.0 mm²/s

[0135] The olefin copolymer thickeners used in the formulations of the examples were concentrates of olefin copolymer, specifically ethylene-propylene copolymer, in a diluent. Accordingly, in the tables set forth below, the weight percentages listed for the OCP thickeners are on an as-received basis, not on an actives basis. To obtain the weight percentage on an actives basis for the olefin copolymer, the listed weight percentage for the OCP thickener should be multiplied by the weight percentage olefin copolymer present in the OCP thickener.

[0136] OCP-1: a concentrate having 6.30 wt. % 50 SSI olefin copolymer in Group II diluent oil and containing 60% ethylene and having a number average molecular weight (Mn) of 112,000 g/mole.

[0137] OCP-2: a concentrate having 10.00 wt. % 24 SSI olefin copolymer in Group II diluent oil and containing 57% ethylene and having a number average molecular weight (Mn) of 40,000 g/mole.

[0138] OCP-3: a concentrate having 18.75 wt. % 35 SSI olefin copolymer in Group II diluent oil and containing 57% ethylene and having a number average molecular weight (Mn) of 49,000 g/mole.

[0139] OCP-4: a concentrate having 8.6 wt. % 50 SSI olefin copolymer in Group II diluent oil and containing 49% ethylene and having a number average molecular weight (Mn) of 84,000 g/mole.

[0140] The additive packages used in the example formulations included:

[0141] Additive Package A: oil concentrate of a high TBN calcium sulfonate detergent, oil concentrate of a MOB calcium sulfurized phenate

detergent, oil concentrate of a LOB calcium sulfurized phenate detergent, oil concentrate of a succinimide dispersant, tracer component, and foam inhibitor.

[0142] Additive Package B: 7.5 wt.% oil concentrate of a 410 BN overbased calcium carboxylate detergent derived from a C₂₀ to C₂₄ isomerized alpha olefin (33.0 wt.% diluent oil), 5.2 wt.% oil concentrate of a 180 BN overbased calcium carboxylate detergent derived from a C₂₀ to C₂₄ isomerized normal alpha olefin (20 wt.% diluent oil), 0.7 wt.% of a secondary zinc dithiophosphate, and 0.1 wt.% of a foam inhibitor.

[0143] Additive Package C: 6.92 wt. % oil concentrate of a 420 BN calcium sulfonate detergent (38.7 wt. % diluent oil), 6.0 wt. % oil concentrate of a 17 BN calcium sulfonate detergent (50.0 wt. % diluent oil), 9.0 wt. % oil concentrate of a 95 BN calcium sulfurized phenate detergent derived from a C₂₀ to C₂₄ isomerized alpha olefin (20 wt. % diluent oil), 0.2 wt. % oil concentrate of bisuccinimide dispersant derived from 1000 MW PIB (32 wt. % diluent oil), 1.5 wt.% antioxidants, 0.11 wt.% of a foam inhibitor and diluent oil.

[0144] Additive Package D: 5.0 wt. % oil concentrate of a 260 BN calcium sulfurized phenate detergent derived from a C₂₀ to C₂₄ isomerized alpha olefin (40 wt. % diluent oil), 4.0 wt.% oil concentrate of a 410 BN overbased calcium carboxylate detergent derived from a C₂₀ to C₂₄ isomerized alpha olefin (33.0 wt.% diluent oil), 5.45 wt.% oil concentrate of a 180 BN overbased calcium carboxylate detergent derived from a C₂₀ to C₂₄ isomerized normal alpha olefin (20 wt.% diluent oil), 0.2 wt. % oil concentrate of bisuccinimide dispersant derived from 1000 MW PIB (32 wt. % diluent oil), 1.5 wt.% antioxidants, 0.11 wt.% of a foam inhibitor and diluent oil.

[0145] The degree of high temperature detergency and oxidative stability were evaluated for the following examples using the tests described below. The results for each of the examples are set forth in Tables 2-5.

Test Methods

Micro Coker

[0146] This method is used to evaluate the high temperature deposit/lacquer formation tendency of land and marine lubricants. A quantity of test oil is put into a shallow trough of a sloping aluminum panel. A temperature gradient is applied to the aluminum panel with the test oil evenly distributed in the shallow trough. The panel is heated, and the temperature at which deposits/lacquer starts to form is determined from the appearance of the panel at the end of the test.

DSC Oxidation Test

[0147] The DSC test is used to evaluate thin film oxidation stability of test oils, in accordance with ASTM D-6186. Heat flow to and from test oil in a sample cup is compared to a reference cup during the test. The Oxidation Onset Temperature is the temperature at which the oxidation of the test oil starts. The Oxidation Induction Time is the time at which the oxidation of the test oil starts. A higher oxidation induction time means better performance. The oxidation reaction is exothermic and is clearly shown by the heat flow. The Oxidation Induction Time is calculated to evaluate the thin film oxidation stability of the test oil.

Modified Institute of Petroleum 48 (MIP-48) Test

[0148] The MIP-48 Test consists of a thermal part and an oxidative part. During both parts of the test the test samples are heated. In the thermal part of the test, nitrogen is passed through a heated oil sample for 24 hours and in parallel during the oxidative part of the test, air is passed through a heated oil sample for 24 hours. The samples are cooled and the viscosities of both samples are determined. The viscosity increase of the test oil caused by oxidation is determined and corrected for the thermal effect. The oxidation-based viscosity increase for each marine lubricating oil composition was calculated by subtracting the kinematic viscosity at 200 °C for the nitrogen-blown sample from the kinematic viscosity at 200 °C for the air-blown sample, and dividing the subtraction product by the kinematic viscosity at 200 °C for the nitrogen blown sample. This is done to correct for potential evaporation effects during the test, or any other thermal effect, thereby focusing on the impact of oxidation. This correction may result in a negative value. Test oils which exhibit

better stability against oxidation-based viscosity increase will result in a lower % absolute value.

Results

Examples 1-4, and Comparative Example A

[0149] Examples 1-4 and Comparative Example A were formulated to 70 BN, SAE 50 viscosity grade (kv @100 °C of 19.5 mm²/s) marine cylinder lubricating oil compositions using Additive Package A at 20.0 wt.%. Comparative Example A was formulated using the more conventional combination of heavy neutral oil RLOP 600R and XOM 2500BS bright stock to achieve the appropriate lubricating oil viscosity. Examples 1-4 each contained a combination of light neutral oil RLOP 100R and olefin copolymer thickener to achieve the appropriate lubricating oil viscosity for the finished lubricant. The listed weight percentages for the OCP thickeners are on an as-received basis. Each of the lubricants were evaluated for high temperature detergency and oxidation performance using the Micro Coker and DSC oxidation test, respectively. The results for each of the examples are set forth in Table 2 below.

TABLE 2

	Comparative A	Example 1 100R + OCP-1	Example 2 100R + OCP-2	Example 3 100R + OCP-3	Example 4 100R + OCP-4
OCP - 1		18.0			
OCP - 2			19.0		
OCP - 3				19.0	
OCP - 4					17.0
RLOP 100R		62.0	61.0	61.0	63.0
RLOP 600R	51.0				
XOM 2500BS	29.0				
DSC, min	19.89	25.51	26.29	26.81	25.85
Micro Coker (200-280 °C), lacquer formation temperature	235	244	242	242	258

[0150] The results set forth in Table 2 show that the marine cylinder lubricating oil compositions containing the combination of light neutral oil RLOP 100R and olefin copolymer thickener exhibited surprisingly better detergency and oxidation performance over Comparative Example A. The performance improvement is demonstrated by higher lacquer formation temperatures and higher oxidation induction times for the inventive examples as compared to the comparative example. Additionally, Examples 1-4 were formulated to achieve SAE 50 viscosity grade without the use of heavy neutral oils and without bright stock in the finished lubricating oil composition.

Example 5 and Comparative Example B

[0151] Example 5 and Comparative Example B were formulated to 40 BN, SAE 40 viscosity grade (kv @100 °C of 14.0 mm²/s) marine trunk piston engine lubricating oil compositions comprising Additive Package B at 13.5 wt.%. Comparative Example B was formulated using the more conventional combination of heavy neutral oil 600R and XOM 2500BS bright stock to achieve the appropriate lubricating oil viscosity. Example 5 contained a combination of light neutral oil 220R and olefin copolymer thickener to achieve the appropriate lubricating oil viscosity for the finished lubricant. The listed weight percentages for the OCP thickeners are on an as-received basis. Each of the lubricants were evaluated for oxidative stability using the DSC oxidation test. The results for each of the examples are set forth in Table 3 below.

TABLE 3

	Comparative B BS + 600R	Example 5 220R + OCP-1
OCP - 1	-	9.62
RLOP 220R	-	76.88
RLOP 600R	78.87	-
XOM 2500BS	7.63	-
DSC, min	27.18	32.09

[0152] The results in Table 3 show that the marine trunk piston engine lubricating oil composition containing the combination of light neutral oil 220R and olefin copolymer thickener exhibited surprisingly better oxidation performance over Comparative Example B. The performance improvement is demonstrated by the higher oxidation induction time for Example 5 when compared to Comparative Example B. Additionally, Example 5 was formulated to achieve SAE 40 viscosity grade without the use of heavy neutral oils and bright stock in the finished lubricating oil composition.

Example 6 and Comparative Example C

[0153] Example 6 and Comparative Example C were formulated to 40 BN, SAE 50 viscosity grade (kv @100 °C of 18.5 mm²/s) marine cylinder lubricating oil compositions comprising Additive Package C at 24.98 wt.%. Comparative Example C was formulated using the more conventional combination of heavy neutral oil 600R and XOM 2500BS bright stock to achieve the appropriate lubricating oil viscosity. Example 6 contained a combination of light neutral oil 220R and olefin copolymer thickener to achieve the appropriate lubricating oil viscosity for the finished lubricant. The listed weight percentages for the OCP thickeners are on an as-received basis. Each of the lubricants were evaluated for oxidative stability using the DSC oxidation test. The results for each of the examples are set forth in Table 4 below.

TABLE 4

	Comparative C BS + 600R	Example 6 220R + OCP-1
OCP - 1	-	12.39
RLOP 220R	-	62.63
RLOP 600R	47.21	-
XOM 2500BS	27.81	-
DSC, min	33.35	36.05

[0154] The results in Table 4 show that the marine cylinder lubricating oil composition containing the combination of light neutral oil 220R and olefin copolymer

thickener exhibited surprisingly better oxidation performance over Comparative Example C. The performance improvement is demonstrated by the higher oxidation induction time for Example 6 when compared to Comparative Example C. Additionally, Example 6 was formulated to achieve SAE 50 viscosity grade without the use of heavy neutral oils and bright stock in the finished lubricating oil composition.

Example 7 and Comparative Example D

[0155] Example 7 and Comparative Example D were formulated to 40 BN, SAE 50 viscosity grade (kv @100 °C of 18.5 mm²/s) marine cylinder lubricating oil compositions comprising Additive Package D at 17.12 wt.%. Comparative Example D was formulated using the more conventional combination of heavy neutral oil 600R and XOM 2500BS bright stock to achieve the appropriate lubricating oil viscosity. Example 7 contained a combination of light neutral oil 220R and olefin copolymer thickener to achieve the appropriate lubricating oil viscosity for the finished lubricant. The listed weight percentages for the OCP thickeners are on an as-received basis. Each of the lubricants were evaluated for oxidative stability using the DSC oxidation test. The results for each of the examples are set forth in Table 5 below.

TABLE 5

	Comparative D BS + 600R	Example 7 220R + OCP-1
OCP - 1	-	13.45
RLOP 220R	-	69.43
RLOP 600R	50.98	-
XOM 2500BS	31.90	-
DSC, min	32.36	35.06

[0156] The results in Table 5 show that the marine cylinder lubricating oil composition containing the combination of light neutral oil 220R and olefin copolymer thickener exhibited surprisingly better oxidation performance over Comparative Example D. The performance improvement is demonstrated by the higher oxidation induction time for

Example 7 when compared to Comparative Example D. Additionally, Example 7 was formulated to achieve SAE 50 viscosity grade without the use of heavy neutral oils and bright stock in the finished lubricating oil composition

[0157] The specific embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms, and can also be used in any appropriate combination. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling within the spirit and scope of this disclosure.

CLAIMS

1. A marine diesel engine lubricating oil composition comprising:
 - (a) at least 40 wt. % of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of from 4.0 to less than 8.5 mm²/s; and
 - (b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000; andwherein the marine diesel engine lubricating oil composition has a TBN of greater than 30 mg KOH/g, and further wherein the marine diesel engine lubricating oil composition is a monograde lubricating oil composition meeting the specifications for SAE J300 revised January 2015 requirements for a SAE 30, SAE 40, SAE 50 or SAE 60 monograde lubricating oil.
2. The composition of claim 1, wherein the one or more olefin copolymers are bimodal and have a content of ethylene units ranging from 30% to 80% by weight relative to the weight of olefin copolymer.
3. The composition of claim 1, wherein the one or more olefin copolymers are present, on an actives basis, at 0.5 to 5 wt. % of the lubricating oil composition.
4. The composition of claim 1, wherein the one or more olefin copolymers are present, on an actives basis, at 1 to 2 wt. % of the lubricating oil composition.
5. The composition of claim 1, wherein the one or more olefin copolymers are the only viscosity modifier present in the lubricating oil composition.
6. The composition of claim 1, wherein the lubricating oil composition does not contain bright stock.
7. The composition of claim 1, wherein the lubricating oil composition has a sulfated ash content of 1.5 wt. % or greater.
8. The composition of claim 1, wherein the lubricating oil composition is a marine cylinder lubricating oil having a TBN of greater than 30 to 200 mg KOH/g.

9. The composition of claim 1, wherein the lubricating oil composition is a marine trunk piston engine oil having a TBN of greater than 30 to 80 mg KOH/g.
10. A method of thickening a lubricating oil composition in a marine diesel internal combustion engine, the method comprising adding to said engine a lubricating oil composition comprising:
- (a) at least 40 wt. % of an oil of lubricating viscosity having a kinematic viscosity at 100°C. of from 4.0 to less than 8.5 mm²/s; and
 - (b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000; and
- wherein the marine diesel lubricating oil composition has a TBN of greater than 30 mg KOH/g, and further wherein the marine diesel lubricating oil composition is a monograde lubricating oil composition meeting the specifications for SAE J300 revised January 2015 requirements for a SAE 30, SAE 40, SAE 50 or SAE 60 monograde lubricating oil.
11. The method of claim 10, wherein the one or more olefin copolymers are present, on an actives basis, at 1 to 2 wt. % of the lubricating oil composition.
12. The method of claim 10, wherein the one or more olefin copolymers are the only viscosity modifier present in the lubricating oil composition.
13. The method of claim 10, wherein the lubricating oil composition does not contain bright stock.
14. The method of claim 10, wherein the lubricating oil composition has a sulfated ash content of 1.5 wt. % or greater.
15. The method of claim 10, wherein the lubricating oil composition is a marine cylinder lubricating oil having a TBN of greater than 30 to 200 mg KOH/g.
16. The method of claim 10, wherein the lubricating oil composition is a marine trunk piston engine oil having a TBN of greater than 30 to 80 mg KOH/g.

17. A method of controlling deposit formation in an internal combustion engine, the method comprising operating the internal combustion engine with a lubricating oil composition comprising:
- (a) at least 40 wt. % of an oil of lubricating viscosity having a kinematic viscosity at 100°C. of from 4.0 to less than 8.5 mm²/s; and
 - (b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000; and
- wherein the marine diesel lubricating oil composition has a TBN of greater than 30 mg KOH/g, and further wherein the marine diesel lubricating oil composition is a monograde lubricating oil composition meeting the specifications for SAE J300 revised January 2015 requirements for a SAE 30, SAE 40, SAE 50 or SAE 60 monograde lubricating oil.
18. The method of claim 17, wherein the one or more olefin copolymers are present, on an actives basis, at 1 to 2 wt. % of the lubricating oil composition.
19. The method of claim 17, wherein the one or more olefin copolymers are the only viscosity modifier present in the lubricating oil composition.
20. The method of claim 17, wherein the lubricating oil composition does not contain bright stock.
21. The method of claim 17, wherein the lubricating oil composition has a sulfated ash content of 1.5 wt. % or greater.
22. The method of claim 17, wherein the lubricating oil composition is a marine cylinder lubricating oil having a TBN of greater than 30 to 200 mg KOH/g.
23. The method of claim 17, wherein the lubricating oil composition is a marine trunk piston engine oil having a TBN of greater than 30 to 80 mg KOH/g.
24. A marine diesel engine lubricating oil composition comprising:
- (a) at least 40 wt. % of an oil of lubricating viscosity having a kinematic viscosity at 100 °C of from 4.0 to less than 8.5 mm²/s; and

(b) one or more olefin copolymers having a number average molecular weight of 30,000 to 120,000, wherein the one or more olefin copolymers are present, on an actives basis, at 1.0 wt. % or greater of the lubricating oil composition; and

wherein the marine diesel engine lubricating oil composition is a monograde lubricating oil composition meeting the specifications for SAE J300 revised January 2015 requirements for a SAE 30, SAE 40, SAE 50 or SAE 60 monograde lubricating oil.

25. The lubricating oil composition of claim 24, wherein the one or more olefin copolymers are present, on an actives basis, at 1.0 wt. % to 5 wt. % of the lubricating oil composition.

26. The lubricating oil composition of claim 24, wherein the lubricating oil composition does not contain bright stock.