LUBRICANT COMPOSITIONS HAVING IMPROVED DISPERSANCY PROPERTIES AND WEAR PERFORMANCE

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ABSTRACT

There is disclosed an additive composition comprising (a) a highly reactive polyisobutyl succinimide dispersant, (b) a polyisobutyl succinimide dispersant, and (c) a grafted olefin copolymer viscosity index improver.
LUBRICANT COMPOSITIONS HAVING IMPROVED DISPERSANCY PROPERTIES AND WEAR PERFORMANCE

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to additive and lubricant compositions. More particularly, the disclosure relates to additive and lubricant compositions exhibiting improved properties for dispersancy and wear protection.

BACKGROUND OF THE DISCLOSURE

[0002] Lubricant compositions for internal combustion engines generally contain additives used to improve the performance characteristics of the lubricant, such as to improve detergency, to reduce engine wear, to provide stability against heat and oxidation, to reduce oil consumption, to act as a dispersant, and to reduce friction loss. Dispersants, for example, function to control sludge, carbon, and varnish produced primarily by the incomplete oxidation of fuel, or impurities in the fuel, or impurities in the base oil used in the lubricant compositions. Such deposits can present significant problems, including increased engine wear and increased oil consumption, among other issues. Therefore, what is needed is an additive system which imparts to lubricant compositions improved properties to combat the problems discussed above.

SUMMARY OF THE DISCLOSURE

[0003] In accordance with the disclosure, there is disclosed an additive composition comprising: (a) a highly reactive polyisobutenyl succinimide dispersant; (b) a polyisobutenyl succinimide dispersant; and (c) a grafted olefin copolymer viscosity index improver.

[0004] In an aspect, there is also disclosed a lubricant composition comprising a major amount of a base oil; and a minor amount of an additive composition comprising: (a) a highly reactive polyisobutenyl succinimide dispersant; (b) a polyisobutenyl succinimide dispersant; and (c) a grafted olefin copolymer viscosity index improver.

[0005] Moreover, there is disclosed a method of improving wear performance in a machine, comprising providing to the machine a composition comprising: (i) a base oil, and (ii) an additive composition comprising: (a) a highly reactive polyisobutenyl succinimide dispersant; (b) a polyisobutenyl succinimide dispersant; and (c) a grafted olefin copolymer viscosity index improver.

[0006] Additionally, there is disclosed a method of lubricating at least one moving part of a machine, said method comprising contacting the at least one moving part with a lubricant composition comprising: (i) a major amount of a base oil; (ii) and a minor amount of an additive composition comprising: (a) a highly reactive polyisobutenyl succinimide dispersant; (b) a polyisobutenyl succinimide dispersant; and (c) a grafted olefin copolymer viscosity index improver.

[0007] Additional objects and advantages of the disclosure will be set forth in part in the description which follows, and can be learned by practice of the disclosure. The objects and advantages of the disclosure will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[0008] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosure, as claimed.

DESCRIPTION OF THE EMBODIMENTS

[0009] The present disclosure generally relates to an additive composition comprising: (a) a highly reactive polyisobutenyl succinimide dispersant; (b) a polyisobutenyl succinimide dispersant; and (c) a grafted olefin copolymer viscosity index improver.

[0010] As used herein, the term "major amount" is understood to mean an amount greater than or equal to 50 wt. %, for example from about 80 to about 98 wt. % relative to the total weight of the composition. Moreover, as used herein, the term "minor amount" is understood to mean an amount less than 50 wt. % relative to the total weight of the composition.

[0011] As used herein, the terms "hydrocarbon", "hydrocarbyl" or "hydrocarbon-based" are understood to mean that the moiety being described has predominantly hydrocarbon character within the context of this disclosure. These include moieties that are purely hydrocarbon in nature, that is, they contain only carbon and hydrogen. They can also include moieties containing substituents or atoms which do not alter the predominantly hydrocarbon character of the moiety. Such substituents can include halo, alkoxo, nitro, etc. These moieties also can contain hetero atoms. Suitable hetero atoms will be apparent to those skilled in the art and include, for example, sulfur, nitrogen, oxygen, and phosphorus. Therefore, while remaining predominantly hydrocarbon in character within the context of this invention, these moieties can contain atoms other than carbon present in a chain or ring otherwise composed of carbon atoms.

[0012] As used herein the term "succinimide" is understood to encompass the completed reaction product from a reaction between a hydrocarbyl substituted succinic acylating agent and a polyamine, and is intended to encompass compounds wherein the product may have amide, amidine, and/or salt linkages in addition to the imide linkage of the type that results from the reaction of a primary amine group and an anhydride moiety.

[0013] As used herein, the term "copolymer" is understood to mean a polymer having more than one type of repeating unit and includes, for example, oligomers, copolymers, terpolymers, and tetrapolymers.

[0014] Dispersants suitable for use as components (a) and (b) in compositions of the present disclosure include, but are not limited to, mixtures of dispersants selected from the group consisting of dispersants derived from highly reactive polyalkylene compounds, and boronated dispersants derived from polyalkylene compounds and highly reactive polyalkylene compounds. Dispersants which can be used include, but are not limited to, amine, alcohol, amide, or ester polar moieties attached to the polymer backbone often via a bridging group.

[0015] In an aspect, succinimides derived from an aliphatic hydrocarbyl substituted succinic acylating agent in which the hydrocarbyl substituent contains an average of at least 40 carbon atoms can be suitable dispersants. Suitable acylating agents can include (i) at least one polyisobutenyl substituted succinic acid or (ii) at least one polyisobutenyl substituted succinic anhydride or (iii) a combination of at least one polyisobutenyl substituted succinic acid and at least one polyisobutenyl substituted succinic anhydride in which the polyisobutenyl substituent in (i), (ii) or (iii) is derived from
polyisobutene or a highly reactive polyisobutene having a number average molecular weight in the range of 400 to 5,000.

[0016] As used herein, “highly reactive” is understood to mean that a number of residual vinylidene double bonds in the compound is greater than about 45%. For example, the number of residual vinylidene double bonds can range from about 50 to about 85%, such as from about 75 to about 85%, in the compound. The percentage of residual vinylidene double bonds in the compound may be determined by well-known methods, such as for example Infra-Red Spectroscopy or C13 Nuclear Magnetic Resonance or a combination thereof. A process for producing such compounds is described, for example, in U.S. Pat. No. 4,152,499. For example, a polyisobutene having a ratio of weight average molecular weight to number average molecular weight ranging from about 1 to about 6 can be useful.

[0017] In an aspect, component (a) can be a polyalkylene succinimide dispersant derived from the polyisobutene (PIB) compound described above, wherein the dispersant has a reactive PIB content of at least about 45%. Component (a) can be a mixture of dispersants having a number average molecular weight ranging from about 800 to about 3,000, such as about 2,100, and reactive PIB contents of from about 50 to about 60%, such as about 55%. In another aspect, component (b) can be a dispersant, or mixture of dispersants, having a number average molecular weight ranging from about 800 to about 3,000, such as about 1,300, and reactive PIB contents of from about 55 to about 65%, such as about 60%. The total chlorine content of the lubricant composition of the present disclosure when dispersants such as components (a) and (b) are used should be below 50 ppm as measured by X-ray Fluorescence (XRF).

[0018] An average acid to polyisobutylene ratio in the dispersant can be about 1:1 or greater. In an aspect, the average acid to polyisobutylene ratio for component (a) can range from about 1.7 to about 2.0, and for component (b) can range from about 1.1 to about 2.1.

[0019] An example of a commercially available HR-PIB succinimide dispersant suitable for use herein as component (a) is HITEC® 1932X, available from Afton Chemical Corp., Richmond, Va. An example of a commercially available boron-containing PIB succinimide dispersant suitable for use herein as component (b) is HITEC® 643D, also available from Afton Chemical Corp., Richmond, Va.

[0020] Any of a variety of known procedures can be used to produce the polyisobutylene. Details concerning procedures for producing polyisobutylene have been extensively described in the patent literature, such as for example in U.S. Pat. No. 4,234,435, the disclosure of which is incorporated herein by reference.

[0021] Another principal reactant used to make the PIB succinimide dispersants is one or a mixture of polyanimes which may have at least one primary amino group in the molecule and which additionally may contain an average of at least two other amino nitrogen atoms in the molecule. In an aspect, the polyanimes should contain at least two primary amino groups in the molecule.

[0022] One suitable type of polyanime comprises alkylene polyanimes such as those represented by the formula

\[
\text{H}_n\text{N}(-\text{CH}_2\text{CH}_3\text{N}(-\text{CH}_2\text{CH}_3\text{N}(-\text{CH}_2\text{CH}_3\text{N})\text{N})\text{H}_m
\]

wherein \(n\) is 2 to about 10, and \(m\) is 0 to 10.

Illustrative are ethylene diamine, diethylene triamine, triethylene tetramine, tetraethylene pentamine, spermine, pentaethylene hexamine, propylene diamine, butylene diamine, hexamethylene diamine, decamethylene diamine, and the like. In an aspect, tetraethylene pentamine or a mixture of ethylene polyanimes which approximates tetraethylene pentamine are useful.

[0033] Another type of polyanime that can be used comprises a hydrocarbyl polyanime containing from about 10 to about 50 wt. % acyclic alkylene polyanimes and from about 50 to about 90 wt. % cyclic alkylene polyanimes. Such mixture can be a mixture comprising polye thylene polyanimes, such as a mixture having an overall average composition approximating that of polye thylene pentamine or a mixture having an overall average composition approximating that of polye thylene tetramine. Another useful mixture has an overall average composition approximating that of polye thylene hexamine. In this connection, the terms “polyalkylene” and “polyethylene”, when utilized in conjunction with such terms as “polyanime”, “tetramine”, “pentamine”, “hexamine”, etc., denote that some of the adjacent nitrogen atoms in the product mixture are joined by a single alkylene group whereas other adjacent nitrogen atoms in the product mixture are joined by two alkylene groups thereby forming a cyclic configuration, i.e., a substituted piperazinyl structure.

[0044] Also suitable are aliphatic polyanimes containing one or more ether oxygen atoms and/or one or more hydroxyl groups in the molecule. Mixtures of various polyanimes of the type referred to above are also suitable.

[0055] In principle, therefore, any polyanime having at least one primary amino group and an average of at least three amino nitrogen atoms in the molecule may be used in forming the succinimides described herein. Product mixtures known in the trade as “triethylene tetramine”, “tetraethylene pentamine”, and “pentaethylene hexamine” can be used.

[0066] Components (a) and (b) can also be boronated dispersants. Accordingly, the additive composition can include a boronated dispersant and a non-boronated dispersant. In an aspect, at least one of component (a) or component (b) is boron-containing. Boronated dispersants can be made by reacting a boron compound or mixture of boron compounds capable of introducing boron-containing species into the dispersants before, during or subsequent to the reaction forming the dispersants. Any boron compound, organic or inorganic, capable of undergoing such reaction may be used. Accordingly, use may be made of such inorganic boron compounds as boron acids and boron oxides, including their hydrates. Examples of organic boron compounds include esters of boron acids, such as orthoborate esters, metaborate esters, binate esters, pyroboric acid esters, and the like. Thus, use may be made of such compounds as, for example, boron acids such as boric acid, boronic acid, tetraboric acid, organic acid, pyroboric acid, esters of such acids, such as mono-, di- and tri-organic esters with alcohols comprising about 1 to about 20 carbon atoms, e.g., methanol, ethanol, propanol, isopropanol, butanol, pentanol, hexanol, octanol, decanol, ethylene glycol, propylene glycol and the like, and boron oxides such as boron oxide and boron oxide hydrate.

[0077] In conducting the foregoing boronation reaction, any temperature at which the desired reaction occurs at a satisfactory reaction rate can be used. Such reactions can be conducted in the presence or absence of an ancillary diluent or liquid reaction medium, such as a mineral lubricating oil.
solvent. If the reaction is conducted in the absence of an ancillary solvent of this type, such can be added to the reaction product on completion of the reaction. In this way, the final product is in the form of a convenient solution in lubricating oil and thus is compatible with a lubricating oil base stock.

[0028] The amount of boron reactant used should be sufficient to introduce up to about 5 wt. %, such as from about 0.05 to about 2.5 wt. %, (expressed as weight % of elemental boron) into the dispersants to provide a weight ratio of boron to nitrogen ranging from about 0.25 to about 1.0.

[0029] Component (a) can be present in the lubricant and additive compositions in any effective amount, which can be readily determined by one of ordinary skill in the art. In an embodiment, the lubricant composition of the present disclosure can comprise from about 1.2 wt. % to about 3.9 wt. %, for example from about 1.8 wt. % to about 3.6 wt. %, of component (a), relative to the total weight of the lubricating composition. In another embodiment, the additive composition of the present disclosure can comprise from about 7.5 wt. % to about 25 wt. %, for example from about 11 wt. % to about 23 wt. %, of component (a), relative to the total weight of the additive composition.

[0030] Component (b) can also be present in the lubricant and additive compositions in any effective amount, which can be readily determined by one of ordinary skill in the art. In an embodiment, the lubricant composition of the present disclosure can comprise from about 1.5 wt. % to about 3.5 wt. %, for example from about 1.7 wt. % to about 2.5 wt. %, of component (b), relative to the total weight of the lubricating composition. In another embodiment, the additive composition of the present disclosure can comprise from about 9.4 wt. % to about 22 wt. %, for example from about 11.25 wt. % to about 13.75 wt. %, of component (b), relative to the total weight of the additive composition.

[0031] Grafted olefin copolymer viscosity index improvers suitable for use as component (c) can be produced using a polymerization reaction that is carried out in the presence of a conventional Ziegler-Natta or metallocene catalyst system. The polymerization medium is not specific and can include solution, slurry, or gas phase processes, known as those skilled in the art. When solution polymerization is employed, the solvent may be any suitable inert hydrocarbon solvent that is liquid under reaction conditions for polymerization of alpha-olefins; examples of satisfactory hydrocarbon solvents include straight chain paraffins comprising from about 5 to about 8 carbon atoms, for example hexane. Suitable solvents can include aromatic hydrocarbons, such as aromatic hydrocarbons having a single benzene nucleus, e.g., benzene, toluene and the like; and saturated cyclic hydrocarbons having boiling point ranges approximating those of the straight chain paraffinic hydrocarbons and aromatic hydrocarbons described above. The solvent selected may be a mixture of one or more of the foregoing hydrocarbons. When slurry polymerization is employed, the liquid phase for polymerization can comprise liquid propylene. In an aspect, the polymerization medium can be free of substances that will interfere with the catalyst components.

[0032] Component (c) can have a number average molecular weight of from about 20,000 to about 150,000, for example from about 10,000 to about 200,000, and as another example from about 30,000 to about 110,000. The number average molecular weight for such copolymers can be determined by several known techniques. A convenient method for such determination is by size exclusion chromatography (also known as gel permeation chromatography (GPC)) which additionally provides molecular weight distribution information.

[0033] In preparing component (c), an olefin copolymer can be reacted (e.g., in a graft reaction) with an acylating agent selected from the group consisting of unsaturated monocarboxylic acid anhydrides, unsaturated dicarboxylic acid anhydrides, and corresponding acids thereof. Non-limiting examples of such acylating agents include acrylic anhydride, methacrylic anhydride, cinnamic anhydride, crotonic anhydride, maleic anhydride, fumaric anhydride, itaconic anhydride, and mixtures thereof.

[0034] The acylating agent can be reacted with the olefin copolymer in an amount to provide 0.3 to 0.75 carboxylic acid groups per 1000 number average molecular weight units of the copolymer backbone, for example 0.3 to 0.5 carboxylic acid groups per 1000 number average molecular weight. As an example, a copolymer substrate with Mn of 20,000 can be grafted with 6 to 15 carboxylic acid groups per polymer chain or 7 to 7.5 moles of maleic anhydride per mole of polymer. A copolymer with Mn of 100,000 can be grafted with 30 to 75 carboxylic acid groups per polymer chain or 15 to 37.5 moles of maleic anhydride per polymer chain.

[0035] Component (c) can be formed using a grafting reaction carried out with the aid of a free-radical initiator either in solution or in bulk, as in an extruder or intensive mixing device. When the polymerization is carried out in hexane solution, it is economically convenient to carry out the grafting reaction in hexane as described in U.S. Pat. Nos. 4,340,689, 4,670,515 and 4,948,842, the disclosures of which are incorporated herein by reference. The resulting copolymer is characterized by having carboxylic acid acylating functionality randomly within its structure.

[0036] In the bulk process for forming component (c), the olefin copolymer is fed to rubber or plastic processing equipment such as an extruder, intensive mixer or masticator, heated to a temperature of 150° to 400° C., and the acylating agent and free-radical initiator are separately co-fed to the molten polymer to effect grafting. The reaction can be carried out optionally with mixing conditions to effect shearing and grafting of the ethylene copolymers according to U.S. Pat. No. 5,075,385, the disclosure of which is incorporated herein by reference. The processing equipment is generally purged with nitrogen to prevent oxidation of the polymer and to aid in venting unreacted reagents and byproducts of the grafting reaction. The residence time in the processing equipment is sufficient to provide for the desired degree of acylation and to allow for purification of the acylated copolymer via venting. Mineral or synthetic lubricating oil may optionally be added to the processing equipment after the venting stage to dissolve the acylated copolymer.

[0037] The free-radical initiators which may be used to graft the acylating agent to the polymer backbone include peroxides, hydroperoxides, peresters, and also azo compounds, such as those which have a boiling point greater than 100° C. and decompose thermally within the grafting temperature range to provide free radicals. Non-limiting examples of these free-radical initiators include azobutyronitrile, dicumyl peroxide, 2,5-dimethylhexane-2,5-bis-tert-tertiary-butyl peroxide and 2,5-dimethylhex-3-ynyl-2,5-bis-tertiary-butyl peroxide. The initiator can be used in an amount of between about 0.005% and about 1% by weight based on the weight of the reaction mixture.
Other methods known in the art for effecting reaction of olefin copolymers with acylating agents (e.g., halogenation reactions, thermal or "ene" reactions or mixtures thereof) can be used instead of the free-radical grafting process. Such reactions are conveniently carried out in mineral oil or bulk by heating the reactants at temperatures of 250°C to 400°C under an inert atmosphere to avoid the generation of free radicals and oxidation byproducts. "Ene" reactions are useful methods of grafting when the ethylene-olefin copolymer contains unsaturation. To achieve the high graft levels, e.g., 0.3 to 0.5 carboxylic groups per 1000 Mo, the "ene" or thermal graft reaction can follow or precede a free radical graft reaction.

The acylating agent, for example maleic anhydride, can generally be used in an amount ranging from about 0.01% to about 10%, for example 0.1% to 2.0%, based on weight of the polymer. The aforesaid acylating agent and free radical initiator can be used in a weight percent ratio range of 1:0.1 to 30:1, such as 3:0.1 to 6:1.

Component (c) can be present in the lubricant and additive compositions in any effective amount, which can be readily determined by one of ordinary skill in the art. In embodiment, the lubricant composition of the present disclosure can comprise from about 0.6 wt. % to about 3.0 wt. %, for example from about 0.8 wt. % to about 2.0 wt. %, of component (c), relative to the total weight of the lubricant composition.

Base oils suitable for use in formulating the disclosed compositions can be selected from any of the synthetic or mineral oils or mixtures thereof. Mineral oils include animal oils and vegetable oils (e.g., castor oil, lard oil) as well as other 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. Oils derived from coal or shale are also suitable. Further, oils derived from a gas-to-liquid process are also suitable.

The base oil can be present in a major amount. The base oil can have any desired viscosity that is suitable for the intended purpose. Examples of suitable engine oil kinematic viscosities can range from about 2 to about 150 cSt and, as a further example, from about 5 to about 15 cSt at 100°C. Thus, for example, base oils can be rated to have viscosity ranges of about SAE 15 to about SAE 250, and as a further example, from about SAE 20W to about SAE 50. Suitable automotive oils also include multi-grade oils such as 15W-40, 20W-50, 75W-140, 80W-90, 85W-140, 85W-60, and the like.

Non-limiting examples of synthetic oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, propylene, polyisobutylene copolymers, etc.); polyalphaolefins such as poly (1-hexenes), poly-(1-octenes), poly-(1-decene), and mixtures thereof; allylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, di-nonylbenzenes, di-(2-ethylhexyl)benzenes, etc.); polyphenyls (e.g., biphenyls, terphenyls, alkylated polyphenyls, etc.); alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs and homologs thereof and the like.

Alkylene oxide polymers and interpolymer and derivatives thereof where the terminal hydroxyl moieties have been modified by esterification, etherification, etc., constitute another class of known synthetic oils that can be used. Such oils are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and aryl ethers of these polyoxyalkylene polymers (e.g., methyl-polysisopropylene glycol ether having an average molecular weight of about 1000, diethyl ether of polyethylene glycol having a molecular weight of about 500-1000, diethyl ether of polypropylene glycol having a molecular weight of about 1000-1500, etc.) or mono- and polycarboxylic esters thereof, for example, the acetic acid esters, mixed C3,8 fatty acid esters, or the C13,16 Ox acid diester of tetraethylene glycol.

Another class of synthetic oils that can be used includes the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinates, alkyl succinic acids, maleic acid, azelaic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, etc.) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, etc.). Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl)sebacate, di-n-hexyl fumarate, dioctyl sebacate, dioctyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebates, the 2-ethyl hexyl diester of linoleic acid dimer, the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethyhexanoic acid and like.

Esters useful as synthetic oils also include those made from C5-12 monobasic acids and polyols and polyol ethers such as neopentyl glycol, trimethyl propane, pentaerythritol, dipentaerythritol, tripentaerythritol, etc.

Hence, the base oil used which can be used to make the compositions as described herein can be selected from any of the base oils in Groups II-V as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. Such base oil groups are as follows:

Group II contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120; Group III contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 120; Group IV are polyalphaolefins (PAO); and Group V include all other base stocks not included in Group I, II, III or IV.

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

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

The polyalphaolefins typically have viscosities in the range of 2 to 100 cSt at 100°C, for example 4 to 8 cSt at 100°C. They can, for example, be oligomers of branched or straight chain alpha-olefins having from about 2 to about 30 carbon atoms, non-limiting examples include polypropenes, polyisobutenes, poly-1-butene, poly-1-hexenes, poly-1-ocenes and poly-1-decene. Included are homopolymers, interpolymers and mixtures.

Regarding the balance of the base stock referred to above, a “Group II base stock” also includes a Group II base stock with which base stock(s) from one or more other
groups can be admixed, provided that the resulting admixture has characteristics falling within those specified above for Group I basestocks.

In an aspect, lubricant compositions of the present disclosure can comprise less than 2% Group I basestock, which contain less than 90% saturates and/or greater than 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120.

Basestocks suitable for use herein can be made using a variety of different processes including but not limited to distillation, solvent refining, hydrogen processing, oligomerisation, esterification, and re-refining.

The base oil can be an oil derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons can be made from synthesis gas containing H₂ and CO using a Fischer-Tropsch catalyst. Such hydrocarbons typically require further processing in order to be useful as the base oil. For example, the hydrocarbons can be hydroisomerized using processes disclosed in U.S. Pat. Nos. 6,103,099 or 6,180,575; hydrocracked and hydroisomerized using processes disclosed in U.S. Pat. Nos. 4,943,672 or 6,096,940; dewaxed using processes disclosed in U.S. Pat. No. 5,882,555; or hydroisomerized and dewaxed using processes disclosed in U.S. Pat. Nos. 6,013,171; 6,080,301; or 6,165,949.

Unrefined, refined and rererefined oils, either mineral or synthetic (as well as mixtures of two or more of any of these) of the type disclosed hereinabove can be used in the base oils. Unrefined oils are those obtained directly from a mineral or synthetic source without further purification treatment. For example, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from primary distillation or ester oil obtained directly from an esterification process and used without further treatment would be an unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, etc. Rererefined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such rererefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives, contaminants, and oil breakdown products.

The compositions disclosed herein can optionally contain additives, such as ash-containing detergents, ashless detergents, overbased detergents, pour point depressants, viscosity index modifiers, ash-containing friction modifiers, ashless friction modifiers, nitrogen-containing friction modifiers, nitrogen-free friction modifiers, esterified friction modifiers, extreme pressure agents, rust inhibitors, antioxidants, corrosion inhibitors, anti-foam agents, and combinations thereof.

For best overall results in terms of affording the properties desired in a lubricant composition for lubricating diesel engines, gasoline engines and natural gas engines, the lubricant can contain a compatible combination of additives of each of the above classes of additives in effective amounts. The various additive materials or classes of materials herein described can be readily purchased commercially or prepared by known procedures or obvious modification thereof. Example effective amounts of the optional additives are described in Table 1. All component amounts are given as a weight percent of the active additive.

<table>
<thead>
<tr>
<th>Component</th>
<th>Example Range A (wt. %)</th>
<th>Example Range B (wt. %)</th>
<th>Example Range C (wt. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antioxidants</td>
<td>0 to 3.0</td>
<td>0.2 to 3.0</td>
<td>0.2 to 2.5</td>
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<tr>
<td>Detergents</td>
<td>0 to 10</td>
<td>1 to 8.0</td>
<td>1 to 5.0</td>
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<td>Viscosity Index</td>
<td>0 to 10</td>
<td>2.0 to 9.0</td>
<td>3.0 to 8.0</td>
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<tr>
<td>Improvers</td>
<td>0 to 2.0</td>
<td>0 to 1.5</td>
<td>0 to 1.2</td>
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<td>Extreme Pressure Agents</td>
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<td></td>
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<tr>
<td>Pour Point</td>
<td>0 to 1.0</td>
<td>0.05 to 0.75</td>
<td>0.05 to 0.5</td>
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<td>Depressants</td>
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<tr>
<td>Corrosion Inhibitors</td>
<td>0 to 3.0</td>
<td>0.2 to 2.0</td>
<td>0.2 to 1.5</td>
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<tr>
<td>Friction Modifiers</td>
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<td>0.1 to 0.5</td>
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<td>Anti-foam Agents</td>
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<tr>
<td>Antiwear Agents</td>
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<td>0 to 1.5</td>
<td>0 to 1.2</td>
</tr>
</tbody>
</table>

According to various embodiments, there is disclosed a method of improving wear performance in a machine, comprising providing to the machine a composition comprising (i) a major amount of a base oil, and (ii) a minor amount of an additive composition comprising: (a) a highly reactive polyisobutylene succinimide dispersant; (b) a polyisobutyl succinimide dispersant; and (c) a grafted olefin copolymer viscosity index improver. In an embodiment, the base oil does not comprise a Group I basestock.

According to various embodiments, there is also disclosed a method of lubricating at least one moving part of a machine, said method comprising contacting the at least one moving part with a lubricant composition comprising (i) a major amount of a base oil; and (ii) a minor amount of an additive composition comprising: a) a highly reactive polyisobutylene succinimide dispersant; (b) a polyisobutylel succinimide dispersant; and (c) a grafted olefin copolymer viscosity index improver.

The machine in the disclosed methods can be selected from the group consisting of spark ignition and compression-ignition internal combustion engines, including diesel engines, marine engines, rotary engines, turbine engines, locomotive engines, propulsion engines, aviation piston engines, stationary power generation engines, continuous power generation engines, and engines comprising silver parts. Moreover, the at least one moving part can be chosen from a gear, piston, bearing, rod, spring, camshaft, crankshaft, rotors, and the like.

The lubricant composition can be any composition that would be effective in lubricating a machine. In an aspect, the composition is selected from the group consisting of medium speed diesel engine oils, passenger car motor oils, and heavy duty diesel engine oils. In an embodiment, the composition is a medium speed diesel engine oil or a heavy duty diesel engine oil.

EXAMPLES

The following examples are illustrative of the invention and its advantageous properties. In these examples as well as elsewhere in this application, all parts and percentages are by weight unless otherwise indicated. It is intended that
these examples are being presented for the purpose of illustration only and are not intended to limit the scope of the invention disclosed herein.

Example 1

Cummins ISB Test

[0064] In this example, a turbocharged, after-cooled 5.9 L in-line six-cylinder medium-duty diesel engine was lubricated by the Examples listed in Table 3. The engine was warmed up by running at 1300 r/min and no load for 2 minutes. The load was increased to 200 Nm for 5 minutes and then increased again to 400 Nm for 5 minutes. Then the speed was increased to 2600 r/min and the load was increased to 600 Nm for 5 minutes.

[0065] After the warm-up, the engine ran for 350 hours under the test conditions shown in Table 2 below. A 120 mL sample of each Example was taken every 25 hours from 0 to 100 hours (Stage A), and every 50 hours from 150 hours to the end of the test (Stage B). The engine was purged (120 mL for Stage A and 30 mL for Stage B) prior to taking each sample to ensure minimal carryover from the previous sample. During Stage A, the purge was returned to the auxiliary oil reservoir; during Stage B, the purge was discarded.

<table>
<thead>
<tr>
<th>TABLE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Parameter</td>
</tr>
<tr>
<td>Time</td>
</tr>
<tr>
<td>Engine speed</td>
</tr>
<tr>
<td>Torque</td>
</tr>
<tr>
<td>Fuel Rate</td>
</tr>
<tr>
<td>Coolant out temp.</td>
</tr>
<tr>
<td>Intake manifold pressure</td>
</tr>
<tr>
<td>Intake manifold temp.</td>
</tr>
<tr>
<td>Inlet air temp.</td>
</tr>
<tr>
<td>Turbine inlet temp.</td>
</tr>
<tr>
<td>Oil pan temp.</td>
</tr>
<tr>
<td>Oil pressure</td>
</tr>
<tr>
<td>Intake air restriction</td>
</tr>
<tr>
<td>Exhaust back pressure</td>
</tr>
<tr>
<td>Fuel temp.</td>
</tr>
<tr>
<td>Fuel lift pump pressure</td>
</tr>
</tbody>
</table>

**Intended set point, but may vary due to cyclic conditions

[0066] Throughout Stage A, the engine was operated for 100 hours of steady-state operation at 1,600 RPM to accumulate 3.25%±0.25% soot in the oil. Readings of all operational data were collected every 6 minutes.

[0067] Throughout Stage B, the engine was operated for about 250 hours on a multi-step, 28-second cycle simulating cyclic operation to induce valve train wear. Readings of all operational data were collected at least every 12 cycles. The averaged results for crosshead mass, tappet mass, and cam lobe wear are shown in Table 3 below. Oil performance was determined by assessing crosshead wear, tappet weight loss, and camshaft wear.

<table>
<thead>
<tr>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition (wt %)</td>
</tr>
<tr>
<td>Grafted olefin copolymer dispersant</td>
</tr>
<tr>
<td>PIB succinimide, glycolated nonylphenol dispersant</td>
</tr>
<tr>
<td>HR-PIB succinimide dispersant</td>
</tr>
<tr>
<td>Boron-containing PIB succinimide disp.</td>
</tr>
<tr>
<td>Pour Point Depressants</td>
</tr>
<tr>
<td>Detergents</td>
</tr>
<tr>
<td>Anti-Wear Agents</td>
</tr>
<tr>
<td>Anti-Oxidants</td>
</tr>
<tr>
<td>Anti-Foam Agents</td>
</tr>
<tr>
<td>Friction Modifiers</td>
</tr>
<tr>
<td>Group II Base Oil Balance</td>
</tr>
<tr>
<td>Sulfated Ash, %</td>
</tr>
<tr>
<td>Phosphorus, %</td>
</tr>
<tr>
<td>Sulfur, %</td>
</tr>
<tr>
<td>Total Base Number (TBN)</td>
</tr>
</tbody>
</table>

**ENGINE TEST RESULTS **

**Cummins ISB**

Crosshead mass, loss, mg avg. | 68.6 | 42.9 |
Tappet mass loss, mg avg. | 5.6 | 1.3 |
Cummins ISM

Crosshead mass, loss, mg avg. | 106.6 | 62.4 |
Top ring mass loss, mg avg. | 41.3 | 43.2 |
IAS Mass Loss, mg avg. | 122.4 | 7.9 |
Filter Plugging Delta P, kPa | 6 | 11 |
Average Sludge, merits | 9.1 | 9.1 |

[0068] As shown in Table 3, comparative Example 1 demonstrated an average cam lobe wear of 68.6 microns, as compared to an average cam lobe wear of 42.9 microns for inventive Example 3. Moreover, comparative Example 1 demonstrated an average crosshead mass loss of 5.6 mg, as compared to an average crosshead mass loss of 1.3 mg. Additionally, comparative Example 1 demonstrated an average tappet mass loss of 103.6 mg, compared to a much less average tappet mass loss of 62.4 mg for inventive Example 3. Thus, the results show that inventive Example 3 provided improved oil performance and wear protection than comparative Example 1.

Example 2

Cummins ISM Test

[0069] In this example, a turbocharged, after-cooled 11 L in-line six-cylinder heavy-duty diesel engine equipped with exhaust gas recirculation (EGR) hardware was lubricated by the Examples listed in Table 3. The engine was warmed up according to the conditions show in Table 4 below.
After warming up, the engine ran for 200 hours under the test conditions shown in Table 5 below. All operational parameters were collected once every 6 minutes, except blowby flowrate, intake and exhaust CO2. The blowby flow-rate was collected once every 8 hours, and intake and exhaust CO2 data were collected once every 10 hours but not during a test stage transition.

A 120 mL sample of each Example was taken at the end of each 25-hour period, and the end-of-test oil samples were taken within 30 minutes of each test completion. The engine was purged by removing a 240 mL purge sample prior to taking each sample to ensure minimal carryover from the previous sample. Each purge sample was returned to the engine oil system.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Stage A</th>
<th>Stage B</th>
<th>Stage C</th>
<th>Stage D</th>
<th>Stage E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage Length</td>
<td>min</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Speed</td>
<td>RPM</td>
<td>700</td>
<td>1200</td>
<td>1600</td>
<td>1600</td>
<td>1600</td>
</tr>
<tr>
<td>Torque</td>
<td>N·m</td>
<td>135</td>
<td>270</td>
<td>540</td>
<td>1085</td>
<td>1470</td>
</tr>
<tr>
<td>Coolant Out Temp.</td>
<td>°C</td>
<td>75 max</td>
<td>75 max</td>
<td>75 max</td>
<td>75 max</td>
<td>75 max</td>
</tr>
<tr>
<td>Oil Gallery Temp.</td>
<td>°C</td>
<td>125 max</td>
<td>125 max</td>
<td>125 max</td>
<td>125 max</td>
<td>125 max</td>
</tr>
<tr>
<td>Intake Manifold Temp.</td>
<td>°C</td>
<td>70 max</td>
<td>70 max</td>
<td>70 max</td>
<td>70 max</td>
<td>70 max</td>
</tr>
</tbody>
</table>

As shown in Table 3, comparative Example 2 demonstrated an average crosshead mass loss of 5.6 mg, as compared to an average crosshead mass loss of 3.9 mg for inventive Example 3. Moreover, comparative Example 1 demonstrated a large average injector adjusting screw (IAS) mass loss of 122.4 mg, as compared to a much smaller average IAS mass loss of 7.9 mg. Thus, the results show that inventive Example 3 provided improved oil performance and wear protection than comparative Example 2.

At numerous places throughout this specification, reference has been made to a number of U.S. patents, published foreign patent applications and published technical papers. All such cited documents are expressly incorporated in full into this disclosure as if fully set forth herein.

For the purposes of this specification and appended claims, unless otherwise indicated, all numbers expressing quantities, percentages or proportions, and other numerical values used in the specification and claims, are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by the present disclosure. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

It is noted that, as used in this specification and the appended claims, the singular forms “a,” “an,” and “the,” include plural referents unless expressly and unequivocally limited to one referent. Thus, for example, reference to “an antioxidant” includes two or more different antioxidants. As used herein, the term “include” and its grammatical variants are intended to be non-limiting, such that recitation of items in a list is not to the exclusion of other like items that can be substituted or added to the listed items.

This invention is susceptible to considerable variation in its practice. Therefore the foregoing description is not intended to limit, and should not be construed as limiting, the invention to the particular exemplifications presented hereinabove. Rather, what is intended to be covered is as set forth in the ensuing claims and the equivalents thereof permitted as a matter of law.

Applicant does not intend to dedicate any disclosed embodiments to the public, and to the extent any disclosed modifications or alterations may not literally fall within the scope of the claims, they are considered to be part of the invention under the doctrine of equivalents.

What is claimed is:

1. An additive composition comprising:
(a) a highly reactive polyisobutenyl succinimide dispersant;
(b) a polyisobutenyl succinimide dispersant; and
(c) a grafted olefin copolymer viscosity index improver.

2. The additive composition of claim 1, wherein component (a) comprises a polyisobutenyl succinimide prepared using high vinylidene polyisobutene having a terminal vinylidene content ranging from about 50 to about 85%.

3. The additive composition of claim 1, wherein component (b) is a highly reactive polyisobutenyl succinimide dispersant.

4. The additive composition of claim 1, wherein at least one of component (a) or component (b) is boron-containing.

5. The additive composition of claim 1, wherein component (a) or component (b) is further reacted with at least one acidic reactant selected from the group consisting of maleic acids, maleic anhydrides, and mixtures thereof.

6. The additive composition of claim 1, wherein component (a) is present in an amount ranging from about 7.5 wt. % to about 25 wt. %, relative to the total weight of the additive composition.

7. The additive composition of claim 1, wherein component (a) is present in an amount ranging from about 11 wt. % to about 23 wt. %, relative to the total weight of the additive composition.

8. The additive composition of claim 1, wherein component (b) is present in an amount ranging from about 9.4 wt. % to about 22 wt. %, relative to the total weight of the additive composition.

9. The additive composition of claim 1, wherein component (b) is present in an amount ranging from about 11.25 wt. % to about 13.75 wt. %, relative to the total weight of the additive composition.

10. A lubricant composition comprising:
a major amount of a base oil; and
a minor amount of an additive composition comprising:
(a) a highly reactive polyisobutenyl succinimide dispersant;
(b) a polyisobutenyl succinimide dispersant; and
(c) a grafted olefin copolymer viscosity index improver.

11. The lubricant composition of claim 10, wherein component (a) comprises a polyisobutenyl succinimide prepared using high vinylidene polyisobutene having a terminal vinylidene content ranging from about 50 to about 85%.

12. The lubricant composition of claim 10, wherein at least one of component (a) or component (b) is boron-containing.

13. The lubricant composition of claim 10, wherein component (a) is present in an amount ranging from about 1.2 wt. % to about 3.9 wt. %, relative to the total weight of the lubricant composition.

14. The lubricant composition of claim 10, wherein component (a) is present in an amount ranging from about 1.8 wt. % to about 3.6 wt. %, relative to the total weight of the lubricant composition.

15. The lubricant composition of claim 10, wherein component (b) is present in an amount ranging from about 1.5 wt. % to about 3.5 wt. %, relative to the total weight of the lubricant composition.

16. The lubricant composition of claim 10, wherein component (b) is present in an amount ranging from about 1.7 wt. % to about 2.3 wt. %, relative to the total weight of the lubricant composition.

17. The lubricant composition of claim 10 wherein component (c) is present in an amount ranging from about 0.6 wt. % to about 3.0 wt. %, relative to the total weight of the lubricant composition.

18. The lubricant composition of claim 10, wherein component (c) is present in an amount ranging from about 0.8 wt. % to about 2.0 wt. %, relative to the total weight of the lubricant composition.

19. A method of improving wear performance in a machine, comprising:
providing to the machine a composition comprising (i) a major amount of a base oil, and (ii) a minor amount of an additive composition comprising:
(a) a highly reactive polyisobutenyl succinimide dispersant;
(b) a polyisobutenyl succinimide dispersant; and
(c) a grafted olefin copolymer viscosity index improver.

20. A method of lubricating at least one moving part of a machine, said method comprising:
contacting the at least one moving part with a lubricant composition comprising (i) a major amount of a base oil; (ii) and a minor amount of an additive composition comprising:
(a) a highly reactive polyisobutenyl succinimide dispersant;
(b) a polyisobutenyl succinimide dispersant; and
(c) a grafted olefin copolymer viscosity index improver.

* * * * *