

GRAFTED POLYMER WITH SOOT HANDLING PROPERTIES

TECHNICAL FIELD

[0001] The present disclosure relates to viscosity index modifiers that have dispersant properties, additive concentrates thereof, and lubricating oil compositions comprising such dispersant viscosity index modifiers and concentrates. The disclosure also relates to the use of lubricant compositions comprising the dispersant viscosity index improvers herein for improving soot or sludge handling characteristics of an engine lubricant composition while minimizing the deterioration of engine seals at the same time.

BACKGROUND

[0002] An engine lubricant provides increased engine protection tending to improve fuel economy and reduce emissions. However, it is generally undesired to sacrifice engine protection and lubricating properties to achieve the benefits of improved fuel economy and reduced emissions, and most lubricants often find a balance between such properties. For example, an increase in the amount of friction modifiers in the lubricant may be beneficial for fuel economy purposes but may lead to reduced ability of the lubricant to handle wear stresses imposed by external contaminants, such as water. Likewise, an increase in the amount of anti-wear agent in the lubricant may provide improved engine protection against wear, but could also increase emissions through various mechanisms, such as being detrimental to catalyst performance.

[0003] Likewise, soot and sludge handling components of the lubricant must achieve a similar balance. For example, the soot and sludge handling properties of the lubricant are often improved as the amount of dispersant in the lubricant is increased, but increasing the amount of dispersant can adversely affect elastomer compatibility. This can happen since dispersants are typically amine-containing-compounds that are detrimental to seals.

Introducing polyaromatic functionality into a dispersant improves the dispersant's ability to control viscosity increases in a lubricating oil characteristic of soot contamination.

Accordingly dispersants reacted with an aromatic anhydride and capped with a cyclic carbonate are believed to provide better soot handling capabilities than conventional dispersants. However, such functionalized dispersants often exhibit poor elastomer compatibility even at relatively low treat rates.

BRIEF DESCRIPTION OF THE FIGURES

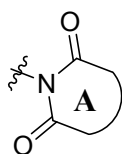
[0004] FIG. 1 is a graph of viscosity (Pa-s) versus shear rate (1/s) for evaluating soot dispersancy of compositions herein.

SUMMARY

[0005] In one aspect, a highly grafted, multi-functional olefin copolymer viscosity modifier is described. The viscosity modifier includes a reaction product of (a) an acylated olefin copolymer including an olefin copolymer having grafted thereon from 0.10 to 0.80 acyl groups per 1000 number average molecular weight units of olefin copolymer and wherein the olefin copolymer has a number average molecular weight of between about 500 and 100,000 (and in other approaches, about 500 to about 40,000); (b) a polyamine compound of Formula I:



c) a dicarboxylic acid or anhydride thereof, which can react with a free primary amine of Formula I to produce a ring moiety A

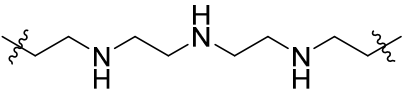


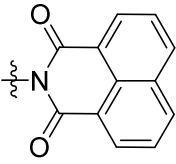
(Ring Moiety A);

wherein ring moiety A is a 5, 6, or 7 membered heterocyclic ring having up to three rings fused thereon, wherein the ring or rings fused thereon are selected from phenyl, carbocyclic, heterocyclic, heteroaryl, or combinations thereof, and wherein ring A is optionally substituted with one or more substituents selected from halo, -CN, oxo, hydroxyl, haloalkyl, C₁₋₄ alkyl, C₁₋₄ alkylcarbonyl, C₁₋₄ alkoxy, C₁₋₄ alkoxy carbonyl, -NH₂, -NH(C₁₋₄ alkyl), and N(C₁₋₄ alkyl)₂. In Formula I, X is a C₂ to C₅₀ alkylene linker unit wherein one or more carbon units are optionally and independently replaced with a bivalent moiety selected from the group consisting of -O-, -NR'-, -NR'NR'-, -C(O)-, -C(O)O-, -C(O)NR', and wherein each X is optionally and independently substituted with one or more R'' substituents; each R' is selected from the group consisting of hydrogen or C₁₋₆ aliphatic, phenyl, or alkylphenyl; and each R'' is independently selected from the group consisting of C₁₋₆ aliphatic, C₃₋₇ cycloalkyl, a 3-7 membered heterocycloalkyl, heteroaryl, and phenyl, wherein R'' is optionally substituted with halo, cyano, amino, hydroxyl, -OR', -C(O)R', -C(O)OR', or -C(O)NR'₂.

[0006] In some embodiments of the aspect from the previous paragraph, X is a polyalkylamine unit of the formula, -(alkylene-NR')_n-alkylene—, and wherein the alkylene

moieties are C₁-C₆ branched or straight alkylene moieties, and n is an integer from 1 to 20;

and/or X is ; and/or X is a polyalkylene glycol unit of the formula, -(alkylene-O)_m-alkylene—, and the alkylene moieties are C₁-C₆ branched or straight alkylene moieties, and m is an integer from 1 to 50; and/or X is a moiety to form a polyether

diamine; and/or wherein ring moiety A is ; and/or wherein the olefin

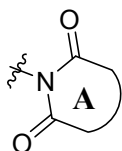
copolymer is a copolymer of ethylene and an alkylene having 3 to 18 carbon atoms; and/or wherein the olefin copolymer has a number average molecular weight of about 500 to about 20,000; and/or wherein the acyl groups grafted on to the olefin copolymer are obtained from acyl reactants that include at least one carbon-carbon double bond and further comprise at least one carboxylic acid and/or dicarboxylic anhydride group; and/or wherein the olefin copolymer has grafted thereon from 0.2 to 0.5 acyl groups per 1000 number average molecular weight units of olefin copolymer.

[0007] Another aspect of the present disclosure includes an additive concentrate including the highly grafted, multi-functional olefin copolymer viscosity modifier as described in the prior two paragraphs. In some approaches, the additive concentrate may include about 10 to about 60 weight percent of the highly grafted, multi-functional olefin copolymer viscosity modifier in a diluent oil.

[0008] In yet another aspect of this disclosure, a lubricating oil composition is provided. The lubricating oil composition includes a major amount of a base oil and a highly grafted, multi-functional olefin copolymer viscosity modifier. In some approaches the high grafted, multi-functional olefin copolymer viscosity modifier includes the reaction product of (a) an acylated olefin copolymer comprising an olefin copolymer having grafted thereon from 0.10 to 0.80 acyl groups per 1000 number average molecular weight units of olefin copolymer and wherein the olefin copolymer has a number average molecular weight of between about 500 and 100,000 (in other approaches, about 500 to about 40,000); (b) a polyamine compound of Formula I:



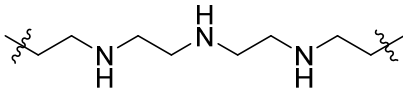
(c) a dicarboxylic acid or anhydride thereof, which can react with a free primary amine of Formula I to produce a ring moiety A

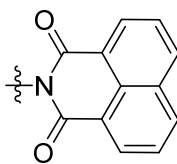


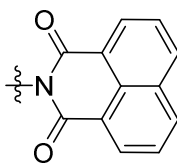
(Ring Moiety A);

wherein ring moiety A is a 5, 6, or 7 membered heterocyclic ring having up to three rings fused thereon, wherein the ring or rings fused thereon are selected from phenyl, carbocyclic, heterocyclic, heteroaryl, or combinations thereof, and wherein ring A is optionally substituted with one or more substituents selected from halo, -CN, oxo, hydroxyl, haloalkyl, C₁₋₄ alkyl, C₁₋₄ alkylcarbonyl, C₁₋₄ alkoxy, C₁₋₄ alkoxy carbonyl, -NH₂, -NH(C₁₋₄ alkyl), and N(C₁₋₄ alkyl)₂. In Formula 1, X is a C₂ to C₅₀ alkylene linker unit wherein one or more carbon units are optionally and independently replaced with a bivalent moiety selected from the group consisting of -O-, -NR'-, -NR'NR'-, -C(O)-, -C(O)O-, -C(O)NR', and wherein each X is optionally and independently substituted with one or more R'' substituents; each R' is selected from the group consisting of hydrogen, C₁₋₆ aliphatic, phenyl, or alkylphenyl; and each R'' is independently selected from the group consisting of C₁₋₆ aliphatic, C₃₋₇ cycloalkyl, a 3-7 membered heterocycloalkyl, heteroaryl, and phenyl, wherein R'' is optionally substituted with halo, cyano, amino, hydroxyl, -OR', -C(O)R', -C(O)OR', or -C(O)NR'₂.

[0009] In some embodiments of the lubricating oil composition aspect of the previous paragraph, X is a polyalkylamine unit of the formula, -(alkylene-NR')_n-alkylene—, and wherein the alkylene moieties are C₁-C₆ branched or straight alkylene moieties, and n is an

integer from 1 to 20; and/or X is ; and/or X is a polyalkylene glycol unit of the formula, -(alkylene-O)_m-alkylene—, and the alkylene moieties are C₁-C₆ branched or straight alkylene moieties, and m is an integer from 1 to 50; and/or X is a moiety



to form a polyether diamine; and/or ring A is ; and/or the olefin copolymer is a copolymer of ethylene and an alkylene having 3 to 18 carbon atoms; and/or the olefin copolymer has a number average molecular weight of about 500 to about 20,000; and/or the acyl groups grafted on to the olefin copolymer are obtained from acyl reactants that include at least one carbon-carbon double bond and further comprise at least one carboxylic acid and/or dicarboxylic anhydride group; and/or the olefin copolymer has grafted thereon from 0.2 to 0.5 acyl groups per 1000 number average molecular weight units of olefin copolymer.

DETAILED DESCRIPTION

[0010] Engine or crankcase lubricant compositions are used in vehicles containing spark ignition and compression ignition engines. Such engines may be used in automotive, truck, and/or train applications, to suggest but a few examples, and may be operated on fuels including, but not limited to, gasoline, diesel, alcohol, compressed natural gas, and the like. The lubricants or lubricant compositions herein may be suitable for use as engine or crankcase lubricants, such as automotive crankcase lubricants that, in some circumstances, meet or exceed the ILSAC GF-5 and/or API CJ-4 lubricant standards.

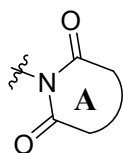
[0011] As noted in the background, engine oils commonly include many additives. Dispersants are a common additive to engine oil to help in diffusing sludge, carbon, soot, oxidation products, and other deposit precursors. Dispersants aid in keeping engine parts clean, prolonging engine life and helping to maintain proper emissions and good fuel economy. The result is reduced deposit formation, less oil oxidation, and less viscosity increase. In some approaches, the dispersants accomplish this by inhibiting particle-to-particle aggregation. Accordingly, the soot and sludge handling properties of the lubricant are improved as the amount of dispersant in the lubricant composition is increased, but increasing the amount of dispersant can in some instances adversely affect elastomeric seals. Described herein, on the other hand, are dispersant viscosity index modifiers, and lubricating oils including such dispersant viscosity index modifiers that have good soot handling properties and viscosity modifying properties and, at the same time, are also less destructive to engine seals (that is, seal friendly) as compared to prior lubricants and prior viscosity modifiers.

[0012] Turning to more of the specifics, a highly grafted, multi-functional olefin copolymer viscosity modifier is described herein. In one aspect, the dispersant viscosity index modifier includes a reaction product of (a) an acylated olefin copolymer; (b) a polyamine; and (c) a dicarboxylic acid or anhydride thereof that can react with primary amines of the reaction product between the acylated olefin copolymer and the polyamine. The selected dicarboxylic acid or anhydrides provides a capping agent of the primary amines to form a ring structure and preferably a capping agent for a terminal primary amine. The capped amines make the dispersant viscosity index modifiers herein more seal friendly but permit the additive to maintain its dispersant and viscosity index properties at the same time.

[0013] In some approaches, the acylated olefin copolymer includes an olefin copolymer having grafted thereon from about 0.10 to about 0.80 acyl groups per 1000 number average molecular weight units of olefin copolymer and wherein the olefin copolymer backbone has a number average molecular weight of between about 500 and 100,000 (in other approaches, about 500 to about 40,000). The polyamine, in some approaches, may be a compound of Formula I:



where X is a C₂ to C₅₀ alkylene linker unit wherein one or more carbon units thereof are optionally and independently replaced with a bivalent moiety selected from the group consisting of -O-, -NR'-, -NR'NR'-, -C(O)-, -C(O)O-, -C(O)NR'. Each X of Formula I may be optionally and independently substituted with one or more R'' substituents. Each R' can be selected from the group consisting of hydrogen or C₁₋₆ aliphatic, phenyl, or alkylphenyl; and each R'' is independently selected from the group consisting of C₁₋₆ aliphatic, C₃₋₇ cycloalkyl, a 3-7 membered heterocycloalkyl, heteroaryl, and phenyl. In some approaches, R'' is optionally substituted with halo, cyano, amino, hydroxyl, -OR', -C(O)R', -C(O)OR', or -C(O)NR'₂. The dicarboxylic acid or anhydride thereof is selected so that it can react with a free primary amine of Formula I to produce a ring moiety A



(Ring Moiety A)

wherein ring moiety A is a 5, 6, or 7 membered heterocyclic ring having up to three rings fused thereon. The ring or rings fused thereon may be selected from phenyl, carbocyclic, heterocyclic, heteroaryl, or combinations thereof, and wherein ring A is optionally substituted with one or more substituents selected from halo, -CN, oxo, hydroxyl, haloalkyl, C₁₋₄ alkyl, C₁₋₄ alkylcarbonyl, C₁₋₄ alkoxy, C₁₋₄ alkoxy carbonyl, -NH₂, -NH(C₁₋₄ alkyl), and N(C₁₋₄ alkyl)₂.

[0014] Polyamine: In some embodiments of Formula I, X may be a polyalkylamine unit of the formula, -(alkylene-NR')_n-alkylene— and wherein R' is defined herein. The alkylene moieties may be C₁-C₆ branched or straight alkylene moieties, and n may be an integer from 1 to 20, for example, 1 to 10, 2 to 8, 2 to 6, or 2 to 4 or other ranges defined within the endpoints 1 and 20. In another approaches, the alkylene moieties of are ethyl, propyl,

isopropyl, butyl, or isobutyl. In a further embodiment, the alkylene moieties are ethyl. In another further embodiment, the alkylene moieties are isopropyl.

[0015] In other approaches of Formula I, X is a polyalkylene glycol unit of the formula, $-(\text{alkylene-O})_m\text{-alkylene}-$ and the alkylene moieties are $\text{C}_1\text{-C}_6$ branched or straight alkylene moieties, and m is an integer from 1 to 50, for example 1 to 30, 1 to 20, 1 to 15, 1 to 10, 1 to 5, 1 to 3, 5 to 10, 10 to 20, 20 to 30, 30 to 40, or 40 to 50. The alkylene moieties may be ethyl, propyl, isopropyl, butyl, or isobutyl. In a further embodiment, the alkylene moieties are ethyl. In another further embodiment, the alkylene moieties are isopropyl. In one approach, X is a moiety to form a polyether diamine.

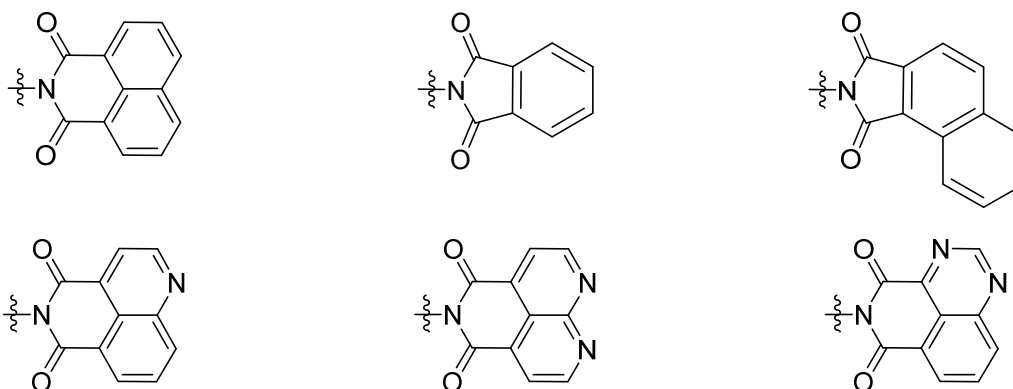
[0016] Each R' of Formula 1 may be independently selected from the group consisting of hydrogen, C_{1-6} aliphatic, phenyl, or alkylphenyl. In other embodiments, each R' is independently selected from the group consisting of hydrogen, methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, n-pentyl, isopentyl, neopentyl, phenyl, and benzyl. In a further embodiment, each R' is independently selected from the group consisting of hydrogen, methyl, ethyl, phenyl, and benzyl. In another further embodiment, each R' is independently selected from the group consisting of hydrogen, methyl, and benzyl. In still another further embodiment, each R' is independently selected from the group consisting of hydrogen and methyl. In another embodiment, each R' is hydrogen.

[0017] Each R'' may be independently selected from the group consisting of C_{3-7} cycloalkyl, a 3-7 membered heterocycloalkyl, heteroaryl, and phenyl, wherein R'' is optionally substituted with halo, cyano, amino, hydroxyl, $-\text{OR}'$, $-\text{C(O)R}'$, $-\text{C(O)OR}'$, or $-\text{C(O)NR}'_2$. In some embodiments of Formula I, each R'' is independently selected from the group consisting of cyclopropyl, cyclopentyl, pyrrolyl, pyridyl, pyrimidyl, piperidyl, morpholino, and phenyl. In some embodiments of Formula I, each R'' is independently selected from the group consisting of cyclopropyl, morpholino, and phenyl. In some embodiments, R'' is unsubstituted.

[0018] Numerous polyamines can be used as the polyamine of Formula 1 in preparing the functionalized dispersant viscosity index modifier. Non-limiting exemplary polyamines may include aminoguanidine bicarbonate (AGBC), diethylene triamine (DETA), triethylene tetramine (TETA), tetraethylene pentamine (TEPA), pentaethylene hexamine (PEHA) and heavy polyamines. A heavy polyamine may comprise a mixture of polyalkylenepolyamines having small amounts of lower polyamine oligomers such as TEPA and PEHA, but primarily oligomers having seven or more nitrogen atoms, two or more primary amines per molecule,

and more extensive branching than conventional polyamine mixtures. Additional non-limiting polyamines which may be used to prepare the hydrocarbyl-substituted succinimide dispersant are disclosed in U.S. Pat. No. 6,548,458, the disclosure of which is incorporated herein by reference in its entirety. In an embodiment of the disclosure, the polyamine may be selected from tetraethylene pentamine (TEPA).

[0019] Amine capping agent: The reaction product of the acylated olefin copolymer and polyamine may further be reacted with a dicarboxylic acid or anhydride thereof that can react with a free primary amine of the formed copolymer/polyamine product to form a ring moiety A as described above to cap primary amines. In one approach, the formed ring moiety A is a 5, 6, or 7 membered heterocyclic ring having up to three rings fused thereon, wherein the ring or rings fused thereon are selected from phenyl, naphthyl, furyl, thiophenyl, 2H-pyrrolyl, pyrrolyl, oxazolyl, thazolyl, imidazolyl, pyrazolyl, isoxazolyl, isothiazolyl, 1,3,4-thiadiazolyl, 2H-pyranlyl, 4-H-pranyl, pyridyl, pyridazyl, pyrimidyl, pyrazolyl, pyrazyl, or 1,3,5-triazyl, or combinations thereof, and wherein ring A is optionally substituted with one or more substituents selected from halo, oxo, hydroxyl, C₁₋₄ alkyl, or -NH₂. In other approaches, the ring moiety A is unsubstituted. In further approaches, the capping agent is selected to form the ring moiety A from the following ring structures wherein the linking nitrogen is part of the polyamine:



[0020] In some approaches, the capping agent may be selected from carboxyl or polycarboxyl acid or polyanhydride wherein the carboxyl acid or anhydride functionalities are directly fused to an aromatic group. Such carboxyl-containing aromatic compound may be selected from 1,8-naphthalic acid or anhydride and 1,2-naphthalenedicarboxylic acid or anhydride, 2,3-dicarboxylic acid or anhydride, naphthalene-1,4-dicarboxylic acid, naphthalene-2,6-dicarboxylic acid, phthalic anhydride, pyromellitic anhydride, 1,2,4-benzene tricarboxylic acid anhydride, diphenic acid or anhydride, 2,3-pyridine dicarboxylic acid or

anhydride, 3,4-pyridine dicarboxylic acid or anhydride, 1,4,5, 8-naphthalenetetracarboxylic acid or anhydride, perylene-3,4,9,10-tetracarboxylic anhydride, pyrene dicarboxylic acid or anhydride, and alike.

[0021] Capping of available primary and/or secondary amines (and preferably terminal primary and/or secondary amines) may be up to 100 percent of the available primary and/or secondary amines to be capped. In other approaches, capping may be about 50 percent to about 100 percent. To this end, the moles of the capping agent reacted per mole of the primary and/or secondary amine may range from about 0.5 to about 1.5, in other approaches, about 0.8 to about 1; and in yet further approaches, about 1. Preferred reaction conditions for the capping is a temperature of about 140°C to about 170°C. In one approach, the capping is a terminal primary and/or secondary amine. In some approaches, secondary amines may also be capped with other compounds such as maleic anhydride and the like.

[0022] Acylated olefin copolymer: The olefin copolymer, in one approach, is a copolymer backbone of ethylene and an alkylene having 3 to 18 carbon atoms, for example 3 to 6, 3 to 10, 3 to 15, 5 to 10, 8 to 12, 10 to 15, or 10 to 18. In some approaches, the alkylene may be propylene, isopropylene, butylene, isobutylene, n-pentylene, isopentylene, and/or neopentylene, and mixtures thereof.

[0023] In some approaches, polymers are copolymers of ethylene and one or more C₃ to C₁₈ alpha-olefins. Copolymers of ethylene and propylene are most preferred. Other alpha-olefins suitable in place of propylene to form the copolymer or to be used in combination with ethylene and propylene to form a terpolymer include 1-butene, 1-pentene, 1-hexene, 1-octene and styrene; aw-diolefins such as 1,5-hexadiene, 1,6-heptadiene, 1,7-octadiene; branched chain alpha-olefins such as 4-methylbutene-1, 5-methylpentene-1 and 6-methylheptene-1; and mixtures thereof.

[0024] More complex polymer substrates, often designated as interpolymers, may be prepared using a third component. The third component generally used to prepare an interpolymer substrate is a polyene monomer selected from non-conjugated dienes and trienes. The non-conjugated diene component is one having from 5 to 14 carbon atoms in the chain. Preferably, the diene monomer is characterized by the presence of a vinyl group in its structure and can include cyclic and bicyclo compounds. Representative dienes include 1,4-hexadiene, 1,4-cyclohexadiene, dicyclopentadiene, 5-ethylidene-2-norbornene, 5-methylene-2-norbornene, 1,5-heptadiene, and 1,6-octadiene. A mixture of more than one diene can be

used in the preparation of the interpolymers. A preferred non-conjugated diene for preparing a terpolymer or interpolymers substrate is 1,4-hexadiene.

[0025] The triene component will have at least two non-conjugated double bonds, and up to about 30 carbon atoms in the chain. Typical trienes useful in preparing the interpolymers of this disclosure are 1-isopropylidene-3a,4,7,7a-tetrahydroindene, 1-isopropylidene dicyclopentadiene, dihydro-isodicyclopentadiene, and 2-(2-methylene-4-methyl-3-pentenyl) [2.2.1] bicyclo-5-heptene.

[0026] Ethylene-propylene or higher alpha-olefin copolymers may consist of from about 15 to 80 mole percent ethylene and from about 85 to 20 mole percent C₃ to C₁₈ alpha-olefin with the preferred mole ratios being from about 35 to 75 mole percent ethylene and from about 65 to 25 mole percent of a C₃ to C₁₈ alpha-olefin, with the more preferred proportions being from 50 to 70 mole percent ethylene and 50 to 30 mole percent C₃ to C₁₈ alpha-olefin, and the most preferred proportions being from 55 to 65 mole percent ethylene and 45 to 35 mole percent C₃ to C₁₈ alpha-olefin.

[0027] Terpolymer variations of the foregoing polymers may contain from about 0.1 to 10 mole percent of a non-conjugated diene or triene.

[0028] The terms polymer and copolymer are used generically to encompass ethylene copolymers, terpolymers or interpolymers. These materials may contain minor amounts of other olefinic monomers so long as the basic characteristics of the ethylene copolymers are not materially changed.

[0029] The polymerization reaction used to form the ethylene-olefin copolymer substrate may be generally 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, as known to 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 having from 5 to 8 carbon atoms, with hexane being preferred. Aromatic hydrocarbons, preferably aromatic hydrocarbon having a single benzene nucleus, such as 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, are particularly suitable. 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 is preferably liquid propylene. It is desirable

that the polymerization medium be free of substances that will interfere with the catalyst components.

[0030] In one embodiment, the olefin copolymer substrate is an ethylene copolymer or terpolymer such as an oil soluble linear or branched polymer having a number average molecular weight of about 500 to about 100,000, for example about 500 to about 40,000, about 500 to about 10,000, about 500 to about 5,000, about 500 to about 3,000, or about 1,000 to about 40,000, about 1,000 to about 20,000, about 5,000 to about 20,000, about 1,000 to about 30,000, about 1,000 to about 10,000, or about 1,000 to about 6,000.

[0031] The acyl groups grafted on to the olefin copolymer are obtained from ethylenically unsaturated carboxylic acid or anhydride reactants that include at least one carbon-carbon double bond and further comprise at least one carboxylic acid and/or dicarboxylic anhydride group. In one approach, the reactants forming the acyl groups grafted on to the olefin copolymer are selected acrylic acid, methacrylic acid, cinnamic acid, ferulic acid, ortho coumaric acid, meta coumaric acid, para coumaric acid, crotonic acid, maleic acid, maleic anhydride, fumaric acid, itaconic acid and itaconic anhydride or a combination thereof. In another approach, the reactants forming the acyl groups grafted on to the olefin copolymer are selected from maleic acid, fumaric acid, maleic anhydride, or a combination thereof. In yet a further approach, the reactants forming the acyl groups grafted on to the olefin copolymer include maleic anhydride moieties.

[0032] In one embodiment, the olefin copolymer has grafted thereon from about 0.1 to about 0.8 acyl groups per 1000 number average molecular weight units of olefin copolymer, for example about 0.2 to about 0.75, about 0.2 to about 0.5, about 0.3 to about 0.5, or about 0.4 to about 0.5, or about 0.1 to about 0.5. In some further embodiments, the olefin copolymer has grafted thereon about 0.2, about 0.3, about 0.4, about 0.5, about 0.6, or about 0.75 acyl groups groups per 1000 number average molecular weight units of olefin copolymer or any range in between such end points.

[0033] The carboxylic reactant is grafted onto the prescribed polymer backbone in an amount to provide about 0.1 to about 0.8 acyl groups per 1000 number average molecular weight units of the polymer backbone, preferably about 0.2 to about 0.5 acyl groups per 1000 number average molecular weight (or other amounts described in the previous paragraph). For example, and in one approach, a copolymer substrate with Mn of 20,000 is grafted with 6 to 15 carboxylic groups per polymer chain or 3 to 7.5 moles of maleic anhydride per mole of polymer. A copolymer with Mn of 100,000 is grafted with 30 to 75 carboxylic groups per

polymer chain or 15 to 37.5 moles of maleic anhydride per polymer chain. The minimum level of functionality is the level needed to achieve the minimum satisfactory dispersancy performance. Above the maximum functionality level little, if any, additional dispersancy performance is noted and other properties of the additive may be adversely affected.

[0034] The grafting reaction to form the acylated olefin copolymers is generally 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 US 4,340,689; US 4,670,515 and US 4,948,842 incorporated herein by reference. The resulting polymer intermediate is characterized by having carboxylic acid acylating functionality randomly within its structure.

[0035] In the bulk process for forming the acylated olefin copolymers, 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 ethylenically unsaturated carboxylic acid reagent and free-radical initiator are separately co-fed to the molten polymer to effect grafting. The reaction is carried out optionally with mixing conditions to effect shearing and grafting of the ethylene copolymers according to US 5,075,383, 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.

[0036] The free-radical initiators which may be used to graft the ethylenically unsaturated carboxylic acid material to the polymer backbone include peroxides, hydroperoxides, peresters, and also azo compounds and preferably those which have a boiling point greater than 100° C. and decompose thermally within the grafting temperature range to provide free radicals. Representatives of these free-radical initiators are azobutyronitrile, dicumyl peroxide, 2,5-dimethylhexane-2,5-bis-tertiarybutyl peroxide and 2,5-dimethylhex-3-yne-2,5-bis-tertiary-butyl peroxide. The initiator is used in an amount of between about 0.005% and about 1% by weight based on the weight of the reaction mixture.

[0037] Other methods known in the art for effecting reaction of ethylene-olefin copolymers with ethylenically unsaturated carboxylic reagents, such as 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 about 250° to about 400° C. under an inert atmosphere to avoid the generation of free radicals and oxidation byproducts. “Ene” reactions are a preferred method of grafting when the ethylene-olefin copolymer contains unsaturation. To achieve the high graft levels, 0.1 to 0.8 acyl groups per 1000 Mn, desired by this disclosure, it may be necessary to follow or proceed the “ene” or thermal graft reaction with a free radical graft reaction.

[0038] DEFINITIONS

[0039] As used herein, the term “effective concentration” refers to the concentration of the viscosity modifier necessary for a sooted base oil to show Newtonian behavior, which indicates that the soot particles in the base oil are sufficiently dispersed.

[0040] As used herein, the term “olefin copolymer” refers to a polymer comprised of two or more different types of monomers, wherein all monomers contain at least one olefin (carbon-carbon double bond).

[0041] A major amount of a compound generally refers to greater than about 50 weight percent.

[0042] For purposes of this disclosure, the chemical elements are identified in accordance with the Periodic Table of the Elements, CAS version, Handbook of Chemistry and Physics, 75th Ed. Additionally, general principles of organic chemistry are described in "Organic Chemistry", Thomas Sorrell, University Science Books, Sausalito: 1999, and "March's Advanced Organic Chemistry", 5th Ed., Ed.: Smith, M.B. and March, J., John Wiley & Sons, New York: 2001, the entire contents of which are hereby incorporated by reference.

[0043] As described herein, compounds may optionally be substituted with one or more substituents, such as are illustrated generally above, or as exemplified by particular classes, subclasses, and species of the disclosure.

[0044] As used herein the term "aliphatic" encompasses the terms alkyl, alkenyl, alkynyl, each of which being optionally substituted as set forth below.

[0045] As used herein, an "alkyl" group refers to a saturated aliphatic hydrocarbon group containing 1-12 (e.g., 1-8, 1-6, or 1-4) carbon atoms. An alkyl group can be straight or branched. Examples of alkyl groups include, but are not limited to, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl, tert-butyl, n-pentyl, n-heptyl, or 2-ethylhexyl. An alkyl

group can be substituted (i.e., optionally substituted) with one or more substituents such as halo, phospho, cycloaliphatic [e.g., cycloalkyl or cycloalkenyl], heterocycloaliphatic [e.g., heterocycloalkyl or heterocycloalkenyl], aryl, heteroaryl, alkoxy, aroyl, heteroaroyl, acyl [e.g., (aliphatic)carbonyl, (cycloaliphatic)carbonyl, or (heterocycloaliphatic)carbonyl], nitro, cyano, amido [e.g., (cycloalkylalkyl)carbonylamino, arylcarbonylamino, aralkylcarbonylamino, (heterocycloalkyl)carbonylamino, (heterocycloalkylalkyl)carbonylamino, heteroarylcarbonylamino, heteroaralkylcarbonylamino alkylaminocarbonyl, cycloalkylaminocarbonyl, heterocycloalkylaminocarbonyl, arylaminocarbonyl, or heteroarylaminocarbonyl], amino [e.g., aliphaticamino, cycloaliphaticamino, or heterocycloaliphaticamino], sulfonyl [e.g., aliphatic-SO₂-], sulfinyl, sulfanyl, sulfoxy, urea, thiourea, sulfamoyl, sulfamide, oxo, carboxy, carbamoyl, cycloaliphaticoxy, heterocycloaliphaticoxy, aryloxy, heteroaryloxy, aralkyloxy, heteroarylalkoxy, alkoxycarbonyl, alkylcarbonyloxy, or hydroxy. Without limitation, some examples of substituted alkyls include carboxyalkyl (such as HOOC-alkyl, alkoxycarbonylalkyl, and alkylcarbonyloxyalkyl), cyanoalkyl, hydroxyalkyl, alkoxyalkyl, acylalkyl, aralkyl, (alkoxyaryl)alkyl, (sulfonylamino)alkyl (such as (alkyl-SO₂-amino)alkyl), aminoalkyl, amidoalkyl, (cycloaliphatic)alkyl, or haloalkyl.

[0046] As used herein, an "alkenyl" group refers to an aliphatic carbon group that contains 2-8 (e.g., 2-12, 2-6, or 2-4) carbon atoms and at least one double bond. Like an alkyl group, an alkenyl group can be straight or branched. Examples of an alkenyl group include, but are not limited to allyl, isoprenyl, 2-butenyl, and 2-hexenyl. An alkenyl group can be optionally substituted with one or more substituents such as halo, phospho, cycloaliphatic [e.g., cycloalkyl or cycloalkenyl], heterocycloaliphatic [e.g., heterocycloalkyl or heterocycloalkenyl], aryl, heteroaryl, alkoxy, aroyl, heteroaroyl, acyl [e.g., (aliphatic) carbonyl, (cycloaliphatic)carbonyl, or (heterocycloaliphatic)carbonyl], nitro, cyano, amido [e.g., (cycloalkylalkyl)carbonylamino, arylcarbonylamino, aralkylcarbonylamino, (heterocycloalkyl) carbonylamino, (heterocycloalkylalkyl)carbonylamino, heteroarylcarbonylamino, heteroaralkylcarbonylamino alkylaminocarbonyl, cycloalkylaminocarbonyl, hetero cycloalkylaminocarbonyl, arylaminocarbonyl, or heteroarylaminocarbonyl], amino [e.g., aliphaticamino, cycloaliphaticamino, heterocycloaliphaticamino, or aliphaticsulfonylamino], sulfonyl [e.g., alkyl-SO₂- , cycloaliphatic-SO₂-, or aryl-SO₂-], sulfinyl, sulfanyl, sulfoxy, urea, thiourea, sulfamoyl, sulfamide, oxo, carboxy, carbamoyl, cycloaliphaticoxy, heterocycloaliphaticoxy, aryloxy, heteroaryloxy, aralkyloxy, heteroaralkoxy, alkoxycarbonyl,

alkylcarbonyloxy, or hydroxy. Without limitation, some examples of substituted alkenyls include cyanoalkenyl, alkoxyalkenyl, acylalkenyl, hydroxyalkenyl, aralkenyl, (alkoxyaryl)alkenyl, (sulfonylamino)alkenyl (such as (alkyl-SO₂-amino)alkenyl), aminoalkenyl, amidoalkenyl, (cycloaliphatic)alkenyl, or haloalkenyl.

[0047] As used herein, an "alkynyl" group refers to an aliphatic carbon group that contains 2-8 (e.g., 2-12, 2-6, or 2-4) carbon atoms and has at least one triple bond. An alkynyl group can be straight or branched. Examples of an alkynyl group include, but are not limited to, propargyl and butynyl. An alkynyl group can be optionally substituted with one or more substituents such as aroyl, heteroaroyl, alkoxy, cycloalkyloxy, heterocycloalkyloxy, aryloxy, heteroaryloxy, aralkyloxy, nitro, carboxy, cyano, halo, hydroxy, sulfo, mercapto, sulfanyl [e.g., aliphaticsulfanyl or cycloaliphaticsulfanyl], sulfinyl [e.g., aliphaticsulfinyl or cycloaliphaticsulfinyl], sulfonyl [e.g., aliphatic-SO₂-, aliphaticamino-SO₂-, or cycloaliphatic-SO₂-], amido [e.g., aminocarbonyl, alkylaminocarbonyl, alkylcarbonylamino, cycloalkylaminocarbonyl, heterocycloalkylaminocarbonyl, cycloalkylcarbonylamino, arylamino carbonyl, arylcarbonylamino, aralkylcarbonylamino, (heterocycloalkyl) carbonylamino, (cycloalkylalkyl)carbonylamino, heteroaralkylcarbonylamino, heteroaryl carbonylamino or heteroarylaminocarbonyl], urea, thiourea, sulfamoyl, sulfamide, alkoxycarbonyl, alkyl carbonyloxy, cycloaliphatic, heterocycloaliphatic, aryl, heteroaryl, acyl [e.g., (cycloaliphatic) carbonyl or (heterocycloaliphatic)carbonyl], amino [e.g., aliphaticamino], sulfoxy, oxo, carboxy, carbamoyl, (cycloaliphatic)oxy, (heterocyclo aliphatic) oxy, or (heteroaryl)alkoxy.

[0048] As used herein, an "amino" group refers to -NR^XR^Y wherein each of R^X and R^Y is independently hydrogen, alkyl, cycloalkyl, (cycloalkyl)alkyl, aryl, aralkyl, heterocycloalkyl, (heterocycloalkyl)alkyl, heteroaryl, carboxy, sulfanyl, sulfinyl, sulfonyl, (alkyl)carbonyl, (cycloalkyl)carbonyl, ((cycloalkyl)alkyl)carbonyl, arylcarbonyl, (aralkyl)carbonyl, (heterocycloalkyl)carbonyl, ((heterocycloalkyl)alkyl)carbonyl, (heteroaryl)carbonyl, or (heteroaralkyl)carbonyl, each of which being defined herein and being optionally substituted. Examples of amino groups include alkylamino, dialkylamino, or arylamino. When the term "amino" is not the terminal group (e.g., alkylcarbonylamino), it is represented by -NR^X-. R^X has the same meaning as defined above.

[0049] As used herein, a "cycloalkyl" group refers to a saturated carbocyclic mono- or bicyclic (fused or bridged) ring of 3-10 (e.g., 5-10) carbon atoms. Examples of cycloalkyl groups include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, adamantyl, norbornyl, cubyl, octahydro-indenyl, decahydro-naphthyl, bicyclo[3.2.1]octyl, bicyclo[2.2.2]

octyl, bicyclo[3.3.1]nonyl, bicyclo[3.3.2.]decyl, bicyclo[2.2.2]octyl, adamantyl, or ((aminocarbonyl)cycloalkyl)cycloalkyl.

[0050] As used herein, a "heterocycloalkyl" group refers to a 3-10 membered mono- or bicyclic (fused or bridged) (e.g., 5- to 10-membered mono- or bicyclic) saturated ring structure, in which one or more of the ring atoms is a heteroatom (e.g., N, O, S, or combinations thereof). Examples of a heterocycloalkyl group include piperidyl, piperazyl, tetrahydropyranyl, tetrahydrofuryl, 1,4-dioxolanyl, 1,4-dithianyl, 1,3-dioxolanyl, oxazolidyl, isoxazolidyl, morpholinyl, thiomorpholyl, octahydrobenzofuryl, octahydrochromenyl, octahydrothiochromenyl, octahydroindolyl, octahydropyrindinyl, decahydroquinolyl, octahydrobenzo[*b*]thiophenyl, 2-oxa-bicyclo[2.2.2]octyl, 1-aza-bicyclo[2.2.2]octyl, 3-aza-bicyclo[3.2.1]octyl, and 2,6-dioxa-tricyclo[3.3.1.0]nonyl. A monocyclic heterocycloalkyl group can be fused with a phenyl moiety to form structures, such as tetrahydroisoquinoline, which would be categorized as heteroaryls.

[0051] A "heteroaryl" group, as used herein, refers to a monocyclic, bicyclic, or tricyclic ring system having 4 to 15 ring atoms wherein one or more of the ring atoms is a heteroatom (e.g., N, O, S, or combinations thereof) and in which the monocyclic ring system is aromatic or at least one of the rings in the bicyclic or tricyclic ring systems is aromatic. A heteroaryl group includes a benzofused ring system having 2 to 3 rings. For example, a benzofused group includes benzo fused with one or two 4 to 8 membered heterocycloaliphatic moieties (e.g., indolizyl, indolyl, isoindolyl, 3H-indolyl, indolinyl, benzo[*b*]furyl, benzo[*b*]thiophenyl, quinolyl, or isoquinolyl). Some examples of heteroaryl are azetidyl, pyridyl, 1H-indazolyl, furyl, pyrrolyl, thienyl, thiazolyl, oxazolyl, imidazolyl, tetrazolyl, benzofuryl, isoquinolyl, benzthiazolyl, xanthene, thioxanthene, phenothiazine, dihydroindole, benzo[1,3]dioxole, benzo[*b*]furyl, benzo[*b*]thiophenyl, indazolyl, benzimidazolyl, benzthiazolyl, puryl, cinnolyl, quinolyl, quinazolyl, cinnolyl, phthalazyl, quinazolyl, quinoxalyl, isoquinolyl, 4H-quinolizyl, benzo-1,2,5-thiadiazolyl, or 1,8-naphthyridyl.

[0052] Without limitation, monocyclic heteroaryls include furyl, thiophenyl, 2H-pyrrolyl, pyrrolyl, oxazolyl, thazolyl, imidazolyl, pyrazolyl, isoxazolyl, isothiazolyl, 1,3,4-thiadiazolyl, 2H-pyranyl, 4-H-pranyl, pyridyl, pyridazyl, pyrimidyl, pyrazolyl, pyrazyl, or 1,3,5-triazyl. Monocyclic heteroaryls are numbered according to standard chemical nomenclature.

[0053] Without limitation, bicyclic heteroaryls include indolizyl, indolyl, isoindolyl, 3H-indolyl, indolinyl, benzo[*b*]furyl, benzo[*b*]thiophenyl, quinolyl, isoquinolyl, indolizyl, isoindolyl, indolyl, benzo[*b*]furyl, benzo[*b*]thiophenyl, indazolyl, benzimidazolyl, benzthiazolyl,

purinyl, 4H-quinolizyl, quinolyl, isoquinolyl, cinnolyl, phthalazyl, quinazolyl, quinoxalyl, 1,8-naphthyridyl, or pteridyl. Bicyclic heteroaryls are numbered according to standard chemical nomenclature.

[0054] A hydrocarbyl group refers to a group that has a carbon atom directly attached to a remainder of the molecule and each hydrocarbyl group is independently selected from hydrocarbon substituents, and substituted hydrocarbon substituents may contain one or more of halo groups, hydroxyl groups, alkoxy groups, mercapto groups, nitro groups, nitroso groups, amino groups, sulfoxy groups, pyridyl groups, furyl groups, thienyl groups, imidazolyl groups, sulfur, oxygen and nitrogen, and wherein no more than two non-hydrocarbon substituents are present for every ten carbon atoms in the hydrocarbyl group.

[0055] The novel dispersant viscosity index modifiers described herein can be used as part of a lubricating oil composition or provided as an additive concentrate. Accordingly, the lubricating oil compositions or concentrate may further comprise a base oil as described below. In one approach, a lubricant oil composition may include about 0.1 to about 10 weight percent of the capped polymer (not including any diluent oil that may be included with the polymer). In other approaches, the highly grafted multi-functional olefin copolymer viscosity modifier is provided as an additive concentrate in diluent or base oil. The additive concentrate may include about 10 to about 60 weight percent viscosity modifier polymer in diluent or base oil.

Base Oil

[0056] The dispersant viscosity index modifiers of the present disclosure may be blended with a majority of base oil in either a lubricant or additive concentrate. Base oils suitable for use in formulating engine lubricant compositions and/or the metal working compositions (or other lubricating composition) and/or additive concentrates may be selected from any of suitable synthetic oils, animal oils, vegetable oils, mineral oils or mixtures thereof. Animal oils and vegetable oils (e.g., lard oil, castor 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 may be used. Oils derived from coal or shale may also be suitable. The base oil typically may have a viscosity of about 2 to about 15 cSt or, as a further example, about 2 to about 10 cSt at 100° C. Further, an oil derived from a gas-to-liquid process is also suitable.

[0057] Suitable synthetic base oils may include alkyl esters of dicarboxylic acids, polyglycols and alcohols, poly-alpha-olefins, including polybutenes, alkyl benzenes, organic

esters of phosphoric acids, and polysilicone oils. Synthetic oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene isobutylene copolymers, etc.); poly(1-hexenes), poly-(1-octenes), poly(1-decenes), etc. and mixtures thereof; alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di-(2-ethylhexyl)benzenes, etc.); polyphenyls (e.g., biphenyls, terphenyl, alkylated polyphenyls, etc.); alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs and homologs thereof and the like.

[0058] Alkylene oxide polymers and interpolymers and derivatives thereof where the terminal hydroxyl groups have been modified by esterification, etherification, etc., constitute another class of known synthetic oils that may 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-polyisopropylene glycol ether having an average molecular weight of about 1000, diphenyl 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-C₈ fatty acid esters, or the C₁₃ oxo-acid diester of tetraethylene glycol.

[0059] Another class of synthetic oils that may be used includes the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, 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, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl 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-ethylhexanoic acid and the like.

[0060] Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers such as neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, etc.

[0061] Hence, the base oil used which may be used to make the engine and/or metalworking lubricant compositions as described herein 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. Such base oil groups are as follows:

[0062] Table 1

Base Oil Group ¹	Sulfur (wt %)		Saturates (wt. %)	Viscosity Index
Group I	> 0.03	And/or	< 90	80 to 120
Group II	≤ 0.03	And	≥ 90	80 to 120
Group III	≤ 0.03	And	≥ 90	≥ 120
Group IV	all polyalphaolefins (PAOs)			
Group V	all others not included in Groups I-IV			

¹Groups I-III are mineral oil base stocks.

[0063] The base oil may contain a minor or major amount of a poly-alpha-olefin (PAO). Typically, the poly-alpha-olefins are derived from monomers having from about 4 to about 30, or from about 4 to about 20, or from about 6 to about 16 carbon atoms. Examples of useful PAOs include those derived from octene, decene, mixtures thereof, and the like. PAOs may have a viscosity of from about 2 to about 15, or from about 3 to about 12, or from about 4 to about 8 cSt at 100° C. Examples of PAOs include 4 cSt at 100° C poly-alpha-olefins, 6 cSt at 100° C poly-alpha-olefins, and mixtures thereof. Mixtures of mineral oil with the foregoing poly-alpha-olefins may be used.

[0064] The base oil may be an oil derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are 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 may 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. 5,882,505; or hydroisomerized and dewaxed using processes disclosed in U.S. Pat. Nos. 6,013,171; 6,080,301; or 6,165,949.

[0065] Unrefined, refined, and rerefined oils, either natural 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 natural 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. Rerefined 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 rerefined 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.

[0066] The base oil may be combined with the emulsifying agent described herein along with optional additives to provide an engine lubricant composition. Accordingly, the base oil may be present in the engine lubricant composition in a major amount ranging from about 50 wt. % to about 95 wt. % based on a total weight of the lubricant composition.

[0067] Other optional additives of the lubricating oils are described below.

Metal-Containing Detergents

[0068] Metal detergents that may be used with the dispersant reaction product described above generally comprise a polar head with a long hydrophobic tail where the polar head comprises a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal, in which case they are usually described as normal or neutral salts, and would typically have a total base number or TBN (as measured by ASTM D2896) of from about 0 to less than about 150. Large amounts of a metal base may be included by reacting an excess of a metal compound such as an oxide or hydroxide with an acidic gas such as carbon dioxide. The resulting overbased detergent comprises micelles of neutralized detergent surrounding a core of inorganic metal base (e.g., hydrated carbonates). Such overbased detergents may have a TBN of about 150 or greater, such as from about 150 to about 450 or more.

[0069] Detergents that may be suitable for use in the present embodiments include oil-soluble overbased, low base, and neutral sulfonates, phenates, sulfurized phenates, and salicylates of a metal, particularly the alkali or alkaline earth metals, e.g., sodium, potassium, lithium, calcium, and magnesium. More than one metal may be present, for example, both calcium and magnesium. Mixtures of calcium and/or magnesium with sodium may also be suitable. Suitable metal detergents may be overbased calcium or magnesium sulfonates having a TBN of from 150 to 450 TBN, overbased calcium or magnesium phenates or sulfurized phenates having a TBN of from 150 to 300 TBN, and overbased calcium or

magnesium salicylates having a TBN of from 130 to 350. Mixtures of such salts may also be used.

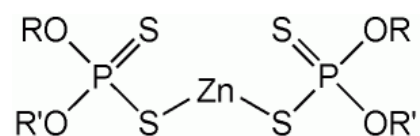
[0070] The metal-containing detergent may be present in a lubricating composition in an amount of from about 0.5 wt % to about 5 wt %. As a further example, the metal-containing detergent may be present in an amount of from about 1.0 wt % to about 3.0 wt %. The metal-containing detergent may be present in a lubricating composition in an amount sufficient to provide from about 500 to about 5000 ppm alkali and/or alkaline earth metal to the lubricant composition based on a total weight of the lubricant composition. As a further example, the metal-containing detergent may be present in a lubricating composition in an amount sufficient to provide from about 1000 to about 3000 ppm alkali and/or alkaline earth metal.

Phosphorus-Based Anti-wear Agents

[0071] Phosphorus-based wear preventative agents may be used and may comprise a metal dihydrocarbyl dithiophosphate compound, such as but not limited to a zinc dihydrocarbyl dithiophosphate compound. Suitable metal dihydrocarbyl dithiophosphates may comprise 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.

[0072] Dihydrocarbyl dithiophosphate metal salts may be prepared in accordance with known techniques by first forming a dihydrocarbyl dithiophosphoric acid (DDPA), usually by reaction of one or more alcohol or a phenol with P_2S_5 and then neutralizing the formed DDPA with a metal compound. For example, a dithiophosphoric acid may be made by reacting mixtures of primary and secondary alcohols. Alternatively, multiple dithiophosphoric acids can be prepared where the hydrocarbyl groups on one are entirely secondary in character and the hydrocarbyl groups on the others are entirely primary in character. To make the metal salt, any basic or neutral metal compound could be used but the oxides, hydroxides and carbonates are most generally employed. Commercial additives frequently contain an excess of metal due to the use of an excess of the basic metal compound in the neutralization reaction.

[0073] The 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, for example 2 to 12, carbon atoms and including radicals such as alkyl, alkenyl, aryl, arylalkyl, alkaryl, and cycloaliphatic radicals. R and R' groups may be alkyl groups of 2 to 8 carbon atoms. Thus, the radicals may, for example, be ethyl, n-propyl, i-propyl, n-butyl, i-butyl, sec-butyl, amyl, n-hexyl, i-hexyl, n-octyl, decyl, dodecyl, octadecyl, 2-ethylhexyl, phenyl, butylphenyl, cyclohexyl, methylcyclopentyl, propenyl, butenyl. In order to obtain oil solubility, the total number of carbon atoms (i.e., R and R') in the dithiophosphoric acid will generally be about 5 or greater. The zinc dihydrocarbyl dithiophosphate can therefore comprise zinc dialkyl dithiophosphates.

[0074] Other suitable components that may be utilized as the phosphorus-based wear preventative include any suitable organophosphorus compound, such as but not limited to, phosphates, thiophosphates, di-thiophosphates, phosphites, and salts thereof and phosphonates. Suitable examples are tricresyl phosphate (TCP), di-alkyl phosphite (e.g., dibutyl hydrogen phosphite), and amyl acid phosphate.

[0075] Another suitable component is a phosphorylated succinimide such as a completed reaction product from a reaction between a hydrocarbyl substituted succinic acylating agent and a polyamine combined with a phosphorus source, such as inorganic or organic phosphorus acid or ester. Further, it may comprise 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 amino group and an anhydride moiety.

[0076] The phosphorus-based wear preventative may be present in a lubricating composition in an amount sufficient to provide from about 200 to about 2000 ppm phosphorus. As a further example, the phosphorus-based wear preventative may be present in a lubricating composition in an amount sufficient to provide from about 500 to about 800 ppm phosphorus.

[0077] The phosphorus-based wear preventative may be present in a lubricating composition in an amount sufficient to provide a ratio of alkali and/or alkaline earth metal content (ppm) based on the total amount of alkali and/or alkaline earth metal in the lubricating composition to phosphorus content (ppm) based on the total amount of phosphorus in the lubricating composition of from about 1.6 to about 3.0 (ppm/ppm).

Friction Modifiers

[0078] Embodiments of the present disclosure may include one or more friction modifiers. Suitable friction modifiers may comprise metal containing and metal-free friction modifiers

and may include, but are not limited to, imidazolines, amides, amines, succinimides, alkoxyated amines, alkoxyated ether amines, amine oxides, amidoamines, nitriles, betaines, quaternary amines, imines, amine salts, amino guanadine, alkanolamides, phosphonates, metal-containing compounds, glycerol esters, and the like.

[0079] Suitable friction modifiers may contain hydrocarbyl groups that are selected from straight chain, branched chain, or aromatic hydrocarbyl groups or admixtures thereof, and may be saturated or unsaturated. The hydrocarbyl groups may be composed of carbon and hydrogen or hetero atoms such as sulfur or oxygen. The hydrocarbyl groups may range from about 12 to about 25 carbon atoms and may be saturated or unsaturated.

[0080] Aminic friction modifiers may include amides of polyamines. Such compounds can have hydrocarbyl groups that are linear, either saturated or unsaturated, or a mixture thereof and may contain from about 12 to about 25 carbon atoms.

[0081] Further examples of suitable friction modifiers include alkoxyated amines and alkoxyated ether amines. Such compounds may have hydrocarbyl groups that are linear, either saturated, unsaturated, or a mixture thereof. They may contain from about 12 to about 25 carbon atoms. Examples include ethoxyated amines and ethoxyated ether amines.

[0082] The amines and amides may be used as such or in the form of an adduct or reaction product with a boron compound such as a boric oxide, boron halide, metaborate, boric acid or a mono-, di- or tri-alkyl borate. Other suitable friction modifiers are described in US 6,300,291, herein incorporated by reference.

[0083] Other suitable friction modifiers may include an organic, ashless (metal-free), nitrogen-free organic friction modifier. Such friction modifiers may include esters formed by reacting carboxylic acids and anhydrides with alkanols. Other useful friction modifiers generally include a polar terminal group (e.g. carboxyl or hydroxyl) covalently bonded to an oleophilic hydrocarbon chain. Esters of carboxylic acids and anhydrides with alkanols are described in U.S. 4,702,850. Another example of an organic ashless nitrogen-free friction modifier is known generally as glycerol monooleate (GMO) which may contain mono- and diesters of oleic acid. Other suitable friction modifiers are described in US Patent No. 6,723,685, herein incorporated by reference. The ashless friction modifier may be present in the lubricant composition in an amount ranging from about 0.1 to about 0.4 percent by weight based on a total weight of the lubricant composition.

[0084] Suitable friction modifiers may also include one or more molybdenum compounds. The molybdenum compound may be selected from the group consisting of molybdenum

[0085] Additionally, the molybdenum compound may be an acidic molybdenum compound. Included are molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdate, and other alkaline metal molybdates and other molybdenum salts, e.g., hydrogen sodium molybdate, MoOCl_4 , MoO_2Br_2 , $\text{Mo}_2\text{O}_3\text{Cl}_6$, molybdenum trioxide or similar acidic molybdenum compounds. Alternatively, the compositions can be provided with molybdenum by molybdenum/sulfur complexes of basic nitrogen compounds as described, for example, in U.S. Pat. Nos. 4,263,152; 4,285,822; 4,283,295; 4,272,387; 4,265,773; 4,261,843; 4,259,195 and 4,259,194; and WO 94/06897.

$$\begin{array}{c} \text{R}_1 \qquad \text{S} \qquad \text{Y}_1 \qquad \text{Y}_2 \qquad \text{S} \qquad \text{R}_3 \\ \diagdown \quad \parallel \quad \diagup \quad \parallel \quad \diagdown \\ \text{N} - \text{C} - \text{S} - \text{Mo} \quad \text{X}_1 \quad \text{Mo} - \text{S} - \text{C} - \text{N} \\ \diagup \quad \quad \quad \diagdown \quad \quad \diagup \quad \quad \diagdown \\ \text{R}_2 \quad \quad \quad \text{X}_2 \quad \quad \text{R}_4 \end{array}$$

[0087] Examples of suitable groups for each of R₁, R₂, R₃, and R₄ include 2-ethylhexyl, nonylphenyl, methyl, ethyl, n-propyl, iso-propyl, n-butyl, t-butyl, n-hexyl, n-octyl, nonyl, decyl, dodecyl, tridecyl, lauryl, oleyl, linoleyl, cyclohexyl and phenylmethyl. R₁ to R₄ may each have C₆ to C₁₈ alkyl groups. X₁ and X₂ may be the same, and Y₁ and Y₂ may be the same. X₁ and X₂ may both comprise sulfur atoms, and Y₁ and Y₂ may both comprise oxygen atoms.

[0089] Another class of suitable organo-molybdenum compounds are trinuclear molybdenum compounds, such as those of the formula $\text{Mo}_3\text{S}_k\text{L}_n\text{Q}_z$ and mixtures thereof, wherein L represents independently selected ligands having organo groups with a sufficient number of carbon atoms to render the compound soluble or dispersible in the oil, n is from 1

to 4, k varies from 4 through 7, Q is selected from the group of neutral electron donating compounds such as water, amines, alcohols, phosphines, and ethers, and z ranges from 0 to 5 and includes non-stoichiometric values. At least 21 total carbon atoms may be present among all the ligands' organo groups, such as at least 25, at least 30, or at least 35 carbon atoms. Additional suitable molybdenum compounds are described in US 6,723,685, herein incorporated by reference.

[0090] The molybdenum compound may be present in a fully formulated engine lubricant in an amount to provide about 5 ppm to 500 ppm by weight molybdenum. As a further example, the molybdenum compound may be present in an amount to provide about 50 to 300 ppm by weight molybdenum. A particularly suitable amount of molybdenum compound may be an amount sufficient to provide from about 60 to about 250 ppm by weight molybdenum to the lubricant composition.

Anti-foam Agents

[0091] In some embodiments, a foam inhibitor may form another component suitable for use in the compositions. Foam inhibitors may be selected from silicones, polyacrylates, and the like. The amount of antifoam agent in the engine lubricant formulations described herein may range from about 0.001 wt% to about 0.1 wt% based on the total weight of the formulation. As a further example, antifoam agent may be present in an amount from about 0.004 wt. % to about 0.008 wt. %.

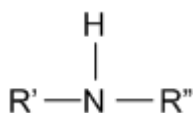
Oxidation Inhibitor Components

[0092] Oxidation inhibitors or antioxidants reduce the tendency of base stocks to deteriorate in service which deterioration can be evidenced by the products of oxidation such as sludge and varnish-like deposits that deposit on metal surfaces and by viscosity growth of the finished lubricant. Such oxidation inhibitors include hindered phenols, sulfurized hindered phenols, alkaline earth metal salts of alkylphenolthioesters having C₅ to C₁₂ alkyl side chains, sulfurized alkylphenols, metal salts of either sulfurized or nonsulfurized alkylphenols, for example calcium nonylphenol sulfide, ashless oil soluble phenates and sulfurized phenates, phosphosulfurized or sulfurized hydrocarbons, phosphorus esters, metal thiocarbamates, and oil soluble copper compounds as described in U.S. Pat. No. 4,867,890.

[0093] Other antioxidants that may be used include sterically hindered phenols and esters thereof, diarylamines, alkylated phenothiazines, sulfurized compounds, and ashless dialkyldithiocarbamates. Non-limiting examples of sterically hindered phenols include, but are not limited to, 2,6-di-tertiary butylphenol, 2,6 di-tertiary butyl methylphenol, 4-ethyl-2,6-

di-tertiary butylphenol, 4-propyl-2,6-di-tertiary butylphenol, 4-butyl-2,6-di-tertiary butylphenol, 4-pentyl-2,6-di-tertiary butylphenol, 4-hexyl-2,6-di-tertiary butylphenol, 4-heptyl-2,6-di-tertiary butylphenol, 4-(2-ethylhexyl)-2,6-di-tertiary butylphenol, 4-octyl-2,6-di-tertiary butylphenol, 4-nonyl-2,6-di-tertiary butylphenol, 4-decyl-2,6-di-tertiary butylphenol, 4-undecyl-2,6-di-tertiary butylphenol, 4-dodecyl-2,6-di-tertiary butylphenol, methylene bridged sterically hindered phenols including but not limited to 4,4-methylenebis(6-tert-butyl-o-cresol), 4,4-methylenebis(2-tert-amyl-o-cresol), 2,2-methylenebis(4-methyl-6 tert-butylphenol, 4,4-methylene-bis(2,6-di-tert-butylphenol) and mixtures thereof as described in U.S Publication No. 2004/0266630.

[0094] Diarylamine antioxidants include, but are not limited to diarylamines having the formula:



wherein R' and R'' each independently represents a substituted or unsubstituted aryl group having from 6 to 30 carbon atoms. Illustrative of substituents for the aryl group include aliphatic hydrocarbon groups such as alkyl having from 1 to 30 carbon atoms, hydroxy groups, halogen radicals, carboxylic acid or ester groups, or nitro groups.

[0095] The aryl group is preferably substituted or unsubstituted phenyl or naphthyl, particularly wherein one or both of the aryl groups are substituted with at least one alkyl having from 4 to 30 carbon atoms, preferably from 4 to 18 carbon atoms, most preferably from 4 to 9 carbon atoms. It is preferred that one or both aryl groups be substituted, e.g. mono-alkylated diphenylamine, di-alkylated diphenylamine, or mixtures of mono- and di-alkylated diphenylamines.

[0096] The diarylamines may be of a structure containing more than one nitrogen atom in the molecule. Thus the diarylamine may contain at least two nitrogen atoms wherein at least one nitrogen atom has two aryl groups attached thereto, e.g. as in the case of various diamines having a secondary nitrogen atom as well as two aryls on one of the nitrogen atoms.

[0097] Examples of diarylamines that may be used include, but are not limited to: diphenylamine; various alkylated diphenylamines; 3-hydroxydiphenylamine; N-phenyl-1,2-phenylenediamine; N-phenyl-1,4-phenylenediamine; monobutyldiphenyl-amine; dibutyldiphenylamine; monooctyldiphenylamine; dioctyldiphenylamine; monononyldiphenylamine; dinonyldiphenylamine; monotetradecyldiphenylamine; ditetradecyldiphenylamine, phenyl-alpha-naphthylamine; monooctyl phenyl-alpha-

naphthylamine; phenyl-beta-naphthylamine; monoheptyldiphenylamine; diheptyldiphenylamine; p-oriented styrenated diphenylamine; mixed butyloctyldi-phenylamine; and mixed octylstyryldiphenylamine.

[0098] The sulfur containing antioxidants include, but are not limited to, sulfurized olefins that are characterized by the type of olefin used in their production and the final sulfur content of the antioxidant. High molecular weight olefins, i.e. those olefins having an average molecular weight of 168 to 351 g/mol, are preferred. Examples of olefins that may be used include alpha-olefins, isomerized alpha-olefins, branched olefins, cyclic olefins, and combinations of these.

[0099] Alpha-olefins include, but are not limited to, any C₄ to C₂₅ alpha-olefins. Alpha-olefins may be isomerized before the sulfurization reaction or during the sulfurization reaction. Structural and/or conformational isomers of the alpha olefin that contain internal double bonds and/or branching may also be used. For example, isobutylene is a branched olefin counterpart of the alpha-olefin 1-butene.

[00100] Sulfur sources that may be used in the sulfurization reaction of olefins include: elemental sulfur, sulfur monochloride, sulfur dichloride, sodium sulfide, sodium polysulfide, and mixtures of these added together or at different stages of the sulfurization process.

[00101] Unsaturated oils, because of their unsaturation, may also be sulfurized and used as an antioxidant. Examples of oils or fats that may be used include corn oil, canola oil, cottonseed oil, grapeseed oil, olive oil, palm oil, peanut oil, coconut oil, rapeseed oil, safflower seed oil, sesame seed oil, soybean oil, sunflower seed oil, tallow, and combinations of these.

[00102] The amount of sulfurized olefin or sulfurized fatty oil delivered to the finished lubricant is based on the sulfur content of the sulfurized olefin or fatty oil and the desired level of sulfur to be delivered to the finished lubricant. For example, a sulfurized fatty oil or olefin containing 20 wt. % sulfur, when added to the finished lubricant at a 1.0 wt. % treat level, will deliver 2000 ppm of sulfur to the finished lubricant. A sulfurized fatty oil or olefin containing 10 wt. % sulfur, when added to the finished lubricant at a 1.0 wt. % treat level, will deliver 1000 ppm sulfur to the finished lubricant. It is desirable that the sulfurized olefin or sulfurized fatty oil to deliver between 200 ppm and 2000 ppm sulfur to the finished lubricant.

[00103] A suitable engine lubricant may include additive components in the ranges listed in Table 2 with broad and narrower ranges, wherein base oil makes up the balance of the lubricant.

[00104] Table 2

Component	Wt. %	Wt. %
Novel dispersant viscosity index modifier polymer*	0.1 to 10	0.1 to 5
Additional Dispersants	0 – 10	1 – 6
Antioxidants	0 – 5	0.01 – 3
Metal Detergents	0 – 15	0.1 – 8
Corrosion Inhibitor	0 – 5	0 – 2
Metal dihydrocarbyl dithiophosphate	0– 6	0.1 – 4
Ash-free amine phosphate salt	0 – 6	0.0 – 4
Antifoaming agents	0 – 5	0.001 – 0.15
Antiwear agents	0 – 1	0 – 0.8
Pour point depressant	0 – 5	0.01 – 1.5
Viscosity modifier	0 – 20	0.25 – 10
Friction modifiers	0 – 2	0.1 – 1

*polymer only (polymer may be provided as a concentrate as described above)

[00105] Additional optional additives that may be included in lubricant compositions described herein include, but are not limited to, rust inhibitors, emulsifiers, demulsifiers, and oil-soluble titanium-containing additives.

[00106] Additives used in formulating the compositions described herein may be blended into the base oil individually or in various sub-combinations. However, it may be suitable to blend all of the components concurrently using an additive concentrate (i.e., additives plus a diluent, such as a hydrocarbon solvent). The use of an additive concentrate may take advantage of the mutual compatibility afforded by the combination of ingredients when in the form of an additive concentrate. Also, the use of a concentrate may reduce blending time and may lessen the possibility of blending errors.

[00107] The present disclosure provides novel lubricating oil blends specifically formulated for use as automotive engine lubricants. Embodiments of the present disclosure may provide lubricating oils suitable for engine applications that provide improvements in one or more of the following characteristics: antioxidancy, antiwear performance, rust inhibition, fuel economy, water tolerance, air entrainment, seal protection, and foam reducing properties.

[00108] A better understanding of the present disclosure and its many advantages may be clarified with the following examples. The following examples are illustrative and not

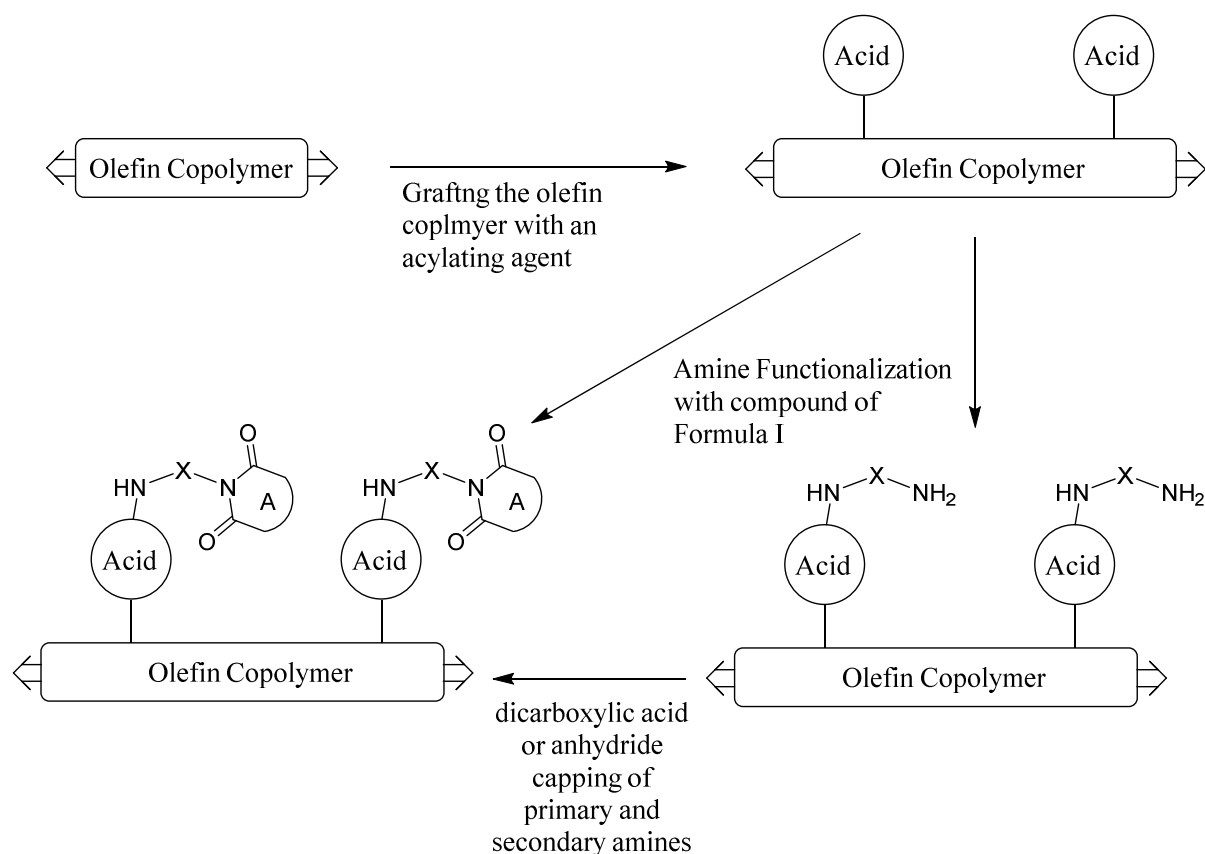
limiting thereof in either scope or spirit. Those skilled in the art will readily understand that variations of the components, methods, steps, and devices described in these examples can be used. Unless noted otherwise or apparent from the context of discussion, all percentages, ratios, and parts noted in this disclosure are by weight.

EXAMPLES

[00109] Materials and Methods

[00110] The reactions described herein were performed in a 500 mL flask with overhead stirring, a water removal condenser, temperature probe, and nitrogen supply. If needed, the reactions were heated using an isomantle.

[00111] **General Synthetic Strategy - Scheme 1:** an exemplary general procedure for the preparation of the highly grafted, multi-functional olefin copolymer viscosity modifiers of the present disclosure with an fused ring anhydride capping agent:



[00112] In the general scheme above, an olefin copolymer is grafted with an acylating agent. The acyl grafting of the olefin polymer may be accomplished with an appropriate technique known to those having skill in the art, such as using carbon radicals produced from an olefin bond using a radical initiator, such as dicumyl peroxide. Other radical initiators are known to those having skill in the art. The grafted acid or anhydride can then undergo

coupling chemistry (in the case of an acid) or a dehydration reaction (in the case of an anhydride) with a compound of Formula I, wherein X and ring A are defined herein. The formation of ring A can be accomplished before or after coupling to the acid functionalized olefin copolymer. In Scheme 1, a coupling reaction of the polymer with the polyamine of Formula I is pictured, but in the case of an anhydride or dicarboxylic acid, such as maleic anhydride, the primary amine of the compound of Formula I would react with both carbonyl moieties of the anhydride to form an imide bond.

[00113] EXAMPLE 1: Maleated low molecular weight OCP reacted with TEPA and capped with Naphthalic Anhydride

[00114] An ethylene propylene copolymer (Mn=5400, 45.54 wt% of reaction mass), and maleic anhydride (Sigma Aldrich , 1.21 wt% of reaction mass) were charged into a two-neck round-bottom flask equipped with a condenser and a Dean Stark apparatus under a nitrogen blanket. The flask was heated to 165°C and held for 1 hour to ensure good dissolution of the polymers. After complete dissolution, dicumyl peroxide (Sigma Aldrich, 0.19 wt% of reaction mass) was charged to the flask, held for 1 hour, and followed by another dicumyl peroxide addition (0.20 wt% of reaction mass). The resulting mixture was allowed to react for 1 hour. After the reaction was complete, the flask was heated to 230°C under vacuum (25 mm Hg) for 4 hours to remove unreacted maleic anhydride. A Group II base oil (Phillip66 110N, 44.07 wt% of reaction mass) was added to the flask and the reaction temperature was set to 165°C. A mixture of tetraethylenepentramine (Sigma Aldrich, TEPA, 1.21 wt% of reaction mass), optional Surfonic L24-2 (Huntsman, 7.00 wt% of reaction mass), and naphthalic anhydride (Sigma Aldrich, 0.57 wt% of reaction mass) was charged to the flask at 165°C, and reacted for 4 hours to provide the final product, which had a kinematic viscosity at 100°C of 176.8 cSt. For this Example, one mixture of the reactants was prepared.

[00115] The final product was tested and shown to have good soot handling properties. Figure 1 shows that the product polymer has an effective concentration in sooted oil of 1.5 wt%. In order to evaluate lubricant formulations according to this disclosure, the capped polymers herein were tested for their ability to disperse soot. Without dispersant, an oil containing soot particles has a shear thinning (non-Newtonian) behavior where viscosity decreases with increasing shear rate due to the agglomeration of soot particles at low shear rate resulting in high viscosity. On the other hand, at higher shear rate, soot particle agglomeration was broken up resulting in low viscosity. If dispersant is added to a sooted oil,

the soot particles are protected by dispersant without agglomeration, thus the oil has an ideally viscous or Newtonian fluid behavior where viscosity is independent of shear rate (See, e.g., Thomas G. Mezger, *The Rheology Handbook*, 3rd Revised Edition, 2011, which is incorporated herein by reference.)

[00116] Based on this principle, a dispersancy test was designed to test effectiveness of the polymer to dispersant soot particles using a Physica MCR 301 Rheometer (Anton Parr). A sooted oil have 4.3 wt.% soot was generated from a fired diesel engine using a lubricating fluid that contains no dispersants. In this test, the sooted oil was then top treated with a certain amount of polymers and then tested by a shear rate sweep in the rheometer with a cone on plate to look for Newtonian/non-Newtonian behavior. Test temperature was 100°C and the test top plate is CP50-1 (Anton Parr). A profile of viscosity and shear rate was recorded, and the results may be seen in Figure 1.

[00117] As shown in FIG. 1, the untreated sooted oil (Curve A containing no dispersant) showed a curve of decreasing viscosity with increasing shear rate, which means that it is a shear thinning (non-Newtonian) fluid and the soot is agglomerating. The higher viscosity at lower shear is a sign of soot agglomeration. About 1.5 weight percent of the inventive polymer from Example 1 in the same sooted oil, on the other hand, exhibited relatively constant viscosity versus shear rate (Curve B). Furthermore, viscosity at low shear is lower than for Curve A. These results show that Example 1 effectively disperse the soot particles at the treat rate used (1.5 weight percent).

[00118] The product polymer also has good elastomer compatibility up to 10% neat polymer treat, as shown in Table 4. The invented polymer of Example 1 was tested for elastomer compatibility in a reference fluid as listed in Tables 3 and 4 below at 0, 2, 5, 10 wt% on neat polymer basis (note Example 1 has a polymer content of about 45.5 wt% in the formed additive concentrate). A fluoroelastomeric rubber was cut into bone-shaped pieces with a Type L die. The rubber pieces were then immersed in 30 mL scintillation vials containing about 22 grams of the oil composition of Table 3 to be tested. The vials were covered with foil and placed in a 150°C oven for seven days. After seven days, the vials were drained and the rubber pieces were blotted to remove excess oil. An elongation rupture test was conducted on each of the rubber pieces both before and after fluid soaking using an Instron and the results are recorded in Table 4. As can be seen, even at very high polymer treat rate (neat polymer at 10.0 wt%), the seal performance is still excellent. This test shows

that the amine capping of the OCP of Example 1 improves the negative effect of the primary amine on elastomeric seals.

[00119] Table 3:

Fluid component	wt%
Invented polymers	(see Table 4)
Dispersants	4.0
Antioxidant	1.25
Metal detergents	1.18
Zinc dihydrocarbyl dithiophosphates	0.47
Anti-wear agent	0.09
Pour point depressants	0.05
Antifoam agent	0.005
Friction modifier	0.02
Base oils	Balance

[00120] Table 4:

Wt% of Neat Polymer from Example 1	Pass > 55%	Pass > 50%
	Avg ER%	Avg TS%
0	-48.21	-40.19
2	-54.11	-43.97
5	-52.27	-45.92
10	-54.11	-47.11

[00121] In Table 4, Avg ER% is the average elongation to rupture compared to the rupture elongation before immersion in the fluid. Likewise, Avg TS% is the reported tensile strength from the Instron at rupture compared to the reported tensile strength rupture before immersion in the fluid.

[00122] EXAMPLE 2: Maleated medium molecular weight OCP reacted with polyether diamine then capped with naphthalic anhydride.

[00123] An ethylene propylene copolymer (Mn=22000, 20.10 wt% of reaction mass), a 110N base oil (9.03 wt% of reaction mass), and maleic anhydride (0.51 wt% of reaction mass) were charged into a two-neck round bottom flask equipped with a condenser and a Dean Stark apparatus under a nitrogen blanket. The flask was heated to 165°C and held for 1 hour to ensure good dissolution of the polymers. After complete dissolution, dicumyl peroxide (0.077 wt% of reaction mass) was charged to the flask, held for 30 minutes, and followed by another dicumyl peroxide addition (0.077 wt% of reaction mass). The resulting mixture was allowed to react for 1 hour. After the reaction was complete, the flask was heated to 230°C under a vacuum of 25 Hg for 4 hours to remove unreacted maleic anhydride. A Group II base oil (Phillip66 110N, 50.72 wt% of reaction mass) was added to the flask and

the reaction temperature was set to 165°C. A polyether diamine (Jeffamine D2000, Huntsman) was then added to the flask and the flask was kept at a temperature of 165°C for 2 hours. A dispersion of 110N base oil (8.42 wt% of reaction mass) and naphthalic anhydride (1.08 wt% of reaction mass) was prepared and added to the reaction mixture. The resulting mixture was held at 165C for 4 hours to provide the final product, which had a kinematic viscosity at 100°C of 383.5 cSt. This Example shows a method using sequential addition of reactants.

[00124] It is to be understood that while the additives and lubricant of this disclosure have been described in conjunction with the detailed description thereof and summary herein, the foregoing description is intended to illustrate and not limit the scope of the disclosure, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the claims. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims.

CLAIMS

WHAT IS CLAIMED IS:

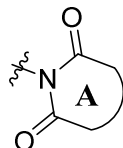
1. An olefin copolymer viscosity modifier comprising the reaction product of

a) an acylated olefin copolymer including an olefin copolymer having grafted thereon from 0.10 to 0.80 acyl groups per 1,000 number average molecular weight units of olefin copolymer and wherein the olefin copolymer has a number average molecular weight of between about 500 and 40,000;

b) a polyamine compound of Formula I:



c) a dicarboxylic acid or anhydride thereof, which can react with a free primary amine of Formula I to produce a ring moiety A



(Ring Moiety A);

wherein

ring moiety A is a 5, 6, or 7 membered heterocyclic ring having up to three rings fused thereon, wherein the ring or rings fused thereon are selected from phenyl, carbocyclic, heterocyclic, heteroaryl, or combinations thereof, and wherein ring A is optionally substituted with one or more substituents selected from halo, -CN, oxo, hydroxyl, haloalkyl, C₁₋₄ alkyl, C₁₋₄ alkylcarbonyl, C₁₋₄ alkoxy, C₁₋₄ alkoxy carbonyl, -NH₂, -NH(C₁₋₄ alkyl), and N(C₁₋₄ alkyl)₂;

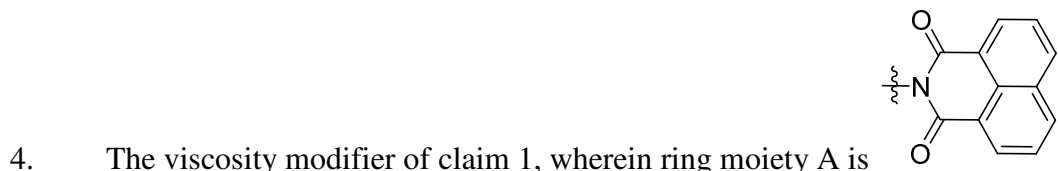
X is a C₂ to C₅₀ alkylene linker unit wherein one or more carbon units are optionally and independently replaced with a bivalent moiety selected from the group consisting of -O-, -NR'-, -NR'NR'-, -C(O)-, -C(O)O-, -C(O)NR', and wherein each X is optionally and independently substituted with one or more R'' substituents;

each R' is selected from the group consisting of hydrogen, C₁₋₆ aliphatic, phenyl, or alkylphenyl; and

each R'' is independently selected from the group consisting of C₁₋₆ aliphatic, C₃₋₇ cycloalkyl, a 3-7 membered heterocycloalkyl, heteroaryl, and phenyl, wherein R'' is optionally substituted with halo, cyano, amino, hydroxyl, -OR', -C(O)R', -C(O)OR', or -C(O)NR'₂.

2. The viscosity modifier of claim 1, wherein X is a polyalkylamine unit of the formula, $-(\text{alkylene-NR}')_n\text{-alkylene}-$, and wherein the alkylene moieties are $\text{C}_1\text{-C}_6$ branched or straight alkylene moieties, and n is an integer from 1 to 20.

3. The viscosity modifier of claim 1, wherein X is a polyalkylene glycol unit of the formula, $-(\text{alkylene-O})_m\text{-alkylene}-$, and the alkylene moieties are $\text{C}_1\text{-C}_6$ branched or straight alkylene moieties, and m is an integer from 1 to 50.



5. The viscosity modifier of claim 1, wherein the olefin copolymer is a copolymer of ethylene and an alkylene having 3 to 18 carbon atoms.

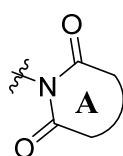
6. An additive concentrate comprising:
a base oil diluent; and
a highly grafted, multi-functional olefin copolymer viscosity modifier comprising the reaction product of

a) an acylated olefin copolymer comprising an olefin copolymer having grafted thereon from 0.10 to 0.80 acyl groups per 1000 number average molecular weight units of olefin copolymer and wherein the olefin copolymer has a number average molecular weight of between about 500 and 40,000;

b) a polyamine compound of Formula I:



c) a dicarboxylic acid or anhydride thereof, which can react with a free primary amine of Formula I to produce a ring moiety A



(Ring Moiety A);

wherein

ring moiety A is a 5, 6, or 7 membered heterocyclic ring having up to three rings fused thereon, wherein the ring or rings fused thereon are selected from phenyl, carbocyclic,

heterocyclic, heteroaryl, or combinations thereof, and wherein ring A is optionally substituted with one or more substituents selected from halo, -CN, oxo, hydroxyl, haloalkyl, C₁₋₄ alkyl, C₁₋₄ alkylcarbonyl, C₁₋₄ alkoxy, C₁₋₄ alkoxycarbonyl, -NH₂, -NH(C₁₋₄ alkyl), and N(C₁₋₄ alkyl)₂;

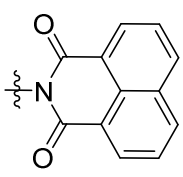
X is a C₂ to C₅₀ alkylene linker unit wherein one or more carbon units are optionally and independently replaced with a bivalent moiety selected from the group consisting of -O-, -NR'-, -NR'NR'-, -C(O)-, -C(O)O-, -C(O)NR', and wherein each X is optionally and independently substituted with one or more R'' substituents;

each R' is selected from the group consisting of hydrogen, C₁₋₆ aliphatic, phenyl, or alkylphenyl; and

each R'' is independently selected from the group consisting of C₁₋₆ aliphatic, C₃₋₇ cycloalkyl, a 3-7 membered heterocycloalkyl, heteroaryl, and phenyl, wherein R'' is optionally substituted with halo, cyano, amino, hydroxyl, -OR', -C(O)R', -C(O)OR', or -C(O)NR'₂.

7. The additive concentrate of claim 6, wherein X is a polyalkylamine unit of the formula, -(alkylene-NR')_n-alkylene—, and wherein the alkylene moieties are C₁-C₆ branched or straight alkylene moieties, and n is an integer from 1 to 20.

8. The additive concentrate of claim 6, wherein X is a polyalkylene glycol unit of the formula, -(alkylene-O)_m-alkylene—, and the alkylene moieties are C₁-C₆ branched or straight alkylene moieties, and m is an integer from 1 to 50.

9. The additive concentrate of claim 6, wherein ring moiety A is .

10. The additive concentrate of claim 6, wherein the concentrate includes about 10 to about 60 weight percent of the highly grafted, multi-functional olefin copolymer viscosity modifier in the base oil diluent.

11. A lubricating oil composition comprising:
a major amount of a base oil; and

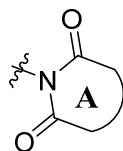
a highly grafted, multi-functional olefin copolymer viscosity modifier comprising the reaction product of

a) an acylated olefin copolymer comprising an olefin copolymer having grafted thereon from 0.10 to 0.80 acyl groups per 1000 number average molecular weight units of olefin copolymer and wherein the olefin copolymer has a number average molecular weight of between about 500 and 40,000;

b) a polyamine compound of Formula I:



c) a dicarboxylic acid or anhydride thereof, which can react with a free primary amine of Formula I to produce a ring moiety A



(Ring Moiety A);

wherein

ring moiety A is a 5, 6, or 7 membered heterocyclic ring having up to three rings fused thereon, wherein the ring or rings fused thereon are selected from phenyl, carbocyclic, heterocyclic, heteroaryl, or combinations thereof, and wherein ring A is optionally substituted with one or more substituents selected from halo, -CN, oxo, hydroxyl, haloalkyl, C₁₋₄ alkyl, C₁₋₄ alkylcarbonyl, C₁₋₄ alkoxy, C₁₋₄ alkoxy carbonyl, -NH₂, -NH(C₁₋₄ alkyl), and N(C₁₋₄ alkyl)₂;

X is a C₂ to C₅₀ alkylene linker unit wherein one or more carbon units are optionally and independently replaced with a bivalent moiety selected from the group consisting of -O-, -NR'-, -NR'NR'-, -C(O)-, -C(O)O-, -C(O)NR', and wherein each X is optionally and independently substituted with one or more R'' substituents;

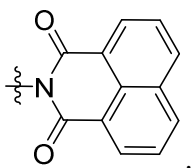
each R' is selected from the group consisting of hydrogen, C₁₋₆ aliphatic, phenyl, or alkylphenyl; and

each R'' is independently selected from the group consisting of C₁₋₆ aliphatic, C₃₋₇ cycloalkyl, a 3-7 membered heterocycloalkyl, heteroaryl, and phenyl, wherein R'' is optionally substituted with halo, cyano, amino, hydroxyl, -OR', -C(O)R', -C(O)OR', or -C(O)NR'₂.

12. The lubricating oil composition of claim 11, wherein X is a polyalkylamine unit of the formula, $-(\text{alkylene-NR}')_n\text{-alkylene}-$, and wherein the alkylene moieties are $\text{C}_1\text{-C}_6$ branched or straight alkylene moieties, and n is an integer from 1 to 20.

13. The lubricating oil composition of claim 11, wherein X is a polyalkylene glycol unit of the formula, $-(\text{alkylene-O})_m\text{-alkylene}-$, and the alkylene moieties are $\text{C}_1\text{-C}_6$ branched or straight alkylene moieties, and m is an integer from 1 to 50.

14. The lubricating oil composition of claim 11, wherein ring moiety A is



15. The lubricating oil composition of claim 11, wherein the lubricating oil composition includes about 0.01 to about 10 weight percent of the highly grafted, multi-functional olefin copolymer viscosity modifier.