DIESTER-BASED ENGINE OIL FORMULATIONS WITH IMPROVED LOW NOACK AND COLD FLOW PROPERTIES

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ABSTRACT

The present invention is generally directed to diester-based multi-grade engine oil formulations. The diesters employed have a number a performance benefits in lubricant applications—among them; biodegradability, extreme temperature performance, oxidative stability, solubility for additives and deposit and sludge precursors, flash and fire points. However, ester usage in lubricants has been quite limited due to their high cost. We utilize new proprietary diesters, structurally different from traditional diesters, which are made from fatty acids and alpha olefins in simple processing steps, yet feature performance similar to more traditional lubricant esters.
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FIELD OF THE INVENTION

[0001] The present invention relates to a multi-grade engine oils formulated to meet the specifications for SAE viscosity grade 0W-XX or 5W-XX engine oil, wherein XX represents the integer 16, 20, 30, or 40. Formulations meeting the specifications for SAE viscosity grade 0W-20 and 5W-20 have been successfully prepared using the present invention. This desired properties achieved include multi-grade 0W-20 and 5W-20 SAE motor oils with low Noack and excellent cold flow properties.

BACKGROUND OF THE INVENTION

[0002] Esters have been used as lubricating oils for over 50 years. They are used in a variety of applications ranging from jet engines, refrigeration and motor oils. In fact, esters were the first synthetic crankcase motor oils in automotive applications. However, esters gave way to polyalphaolefins (PAOs) due to the lower cost of PAOs and their formulation similarities to mineral oils. In full synthetic motor oils, however, esters are almost always used in combination with PAOs to balance the effect on seals, additives solubility, volatility reduction, and energy efficiency improvement by enhanced lubricity. In this aspect, novel diester-based multi-grade engine oil compositions comprising PAOs have been described in commonly-assigned U.S. patent application Ser. No. 12/548,191; filed Aug. 26, 2009.

[0003] Ester-based lubricants, in general, have excellent lubrication properties due to the polarity of the ester molecules of which they are comprised. The polar ester groups of such molecules adhere to positively-charged metal surfaces creating protective films which slow down the wear and tear of the metal surfaces. Such lubricants are less volatile than the traditional lubricants and tend to have much higher flash points and much lower vapor pressures. Ester lubricants are excellent solvents and dispersants, and can readily solvate and disperse the degradation by-products of oils. Therefore, they greatly reduce sludge buildup. While ester lubricants are stable to thermal and oxidative processes, the ester functionality gives microbes a handle to do their biodegrading more efficiently and more effectively than their mineral oil-based analogues. Therefore, there exists an opportunity to employ an alternative blending component that reduces volatility at a reduced cost and with other advantages not afforded with PAO.

[0004] In view of the foregoing, a simpler, more efficient method of generating diester-based multi-grade engine oils would be extremely useful, particularly wherein such methods utilize renewable raw materials in combination with converting low value Fischer-Tropsch (FT) olefins and alcohols to high value diester base oils.

[0005] Novel diester-based lubricant compositions and their corresponding syntheses have been described in commonly-assigned U.S. Pat. No. 7,871,967 B2; issued Jan. 18, 2011. The synthetic routes described in this patent application comprise and/or generally proceed through the following sequence of reaction steps: (1) epoxidation of an olefin to form an epoxide; (2) conversion of the epoxide to form a diol; and (3) esterification of the diol to form a diester.

[0006] Moreover, novel diester-based lubricant compositions and their corresponding syntheses have been described in commonly-assigned U.S. Pat. No. 7,867,959 B2; issued Jan. 11, 2011. The synthetic routes described in this patent application comprise and/or generally proceed through the following sequence of reaction steps: (1) epoxidation of an olefin to form an epoxide; (2) directly esterifying the epoxide with a carboxylic acid to form a diester species.

[0007] Numerous governing organizations, including Original Equipment Manufacturers (OEM's), the American Petroleum Institute (API), Association des Constructeurs d' Automobiles (ACEA), the American Society of Testing and Materials (ASTM), International Lubricant Standardization and Approval Committee (ILSAC), and the Society of Automotive Engineers (SAE), among others, define the specifications for lubricating base oils and engine oils. Increasingly, the specifications for engine oils are calling for products with excellent low temperature properties, high oxidation stability, and low volatility. Currently, only a small fraction of the base oils manufactured today are able to meet these demanding specifications.

[0008] Engine oils are finished crankcase lubricants intended for use in automobile engines and diesel engines and consist of two general components (i.e., a lubricating base oil and additives). Lubricating base oil is the major constituent in these finished lubricants and contributes significantly to the properties of the engine oil. Accordingly, there is need for Multi-grade engine oils formulated lubricating oils, which have improved low volatility, excellent cold flow properties and improved fuel economy to meet today's stringent performance requirements. The minimum specifications for the various viscosity grades of engine oils is established by SAE J300 standards as revised in January 2009.

SUMMARY OF THE INVENTION

[0009] In one embodiment, the present invention is directed to a multi-grade engine oil comprising: a) a diester component, comprising a quantity of at least one diester species having the following Formula I:

\[
\text{R}_1\text{O} - \text{R}_2\text{O} - \text{R}_3\text{R}_4
\]

[0010] wherein \( \text{R}_1, \text{R}_2, \text{R}_3 \), and \( \text{R}_4 \) are the same or independently selected from \( \text{C}_2 \) to \( \text{C}_{12} \) hydrocarbon groups;

[0011] b) a second base oil; and

[0012] c) an additive package.

[0013] wherein the second base is selected from the group consisting of Group I base oil, Group II base oil or Group III base oil.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a chart illustrates the Noack and CCS Viscosity of the diesters of the present invention as compared
to the current commercial esters as presented in Table 6 and other Group II and III bases oils.

**DETAILED DESCRIPTION OF THE INVENTION**

In some embodiments, the present invention is directed to a multi-grade engine oil comprising: a) a diester component, comprising a quantity of at least one diester species of Formula I, wherein R₁, R₂, R₃, and R₄ are the same or independently selected from C₂ to C₁₄ hydrocarbon groups; b) a second base oil; and c) an additive package, wherein the second base oil is selected from the group consisting of Group I base oil, Group II base oil or Group III base oil.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein a quantity of at least one diester species comprises a mixture of isomers where R₁ and R₂ are different for each isomer.

In some embodiments, the present invention is directed to a multi-grade engine oil, further comprising, a third base oil.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein the diester has a Noack Volatility between about 6 and 10 wt %, a CCS Viscosity at −30°C between about 700 and 2000 cP, a pour point less than about −10°C, a cloud point less than about −10°C, a kinematic viscosity at 100°C between about 2.5 to 6.5 centistokes, a VI greater than about 110 and a BN Oxidator greater than about 20 hours.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein the diester has a Noack Volatility between about 6 and 9 wt %, and a CCS Viscosity at −30°C between about 800 and 1900 cP.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein the diester has a Noack Volatility between about 6 and 9 wt %, and a CCS Viscosity at −25°C between about 400 and 1250 cP.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein the second base and third base oil are independently selected from the group consisting of light neutral base oil, medium neutral base oil, Yubase 4, Yubase 6, 150R, 600R, 110R/IV, 220R and 100R.

In some embodiments, the present invention is directed to a multi-grade engine oil, meeting the specifications for SAE viscosity grade 0W-XX or 5W-XX, wherein XX represents the integer 16, 20, 30, or 40.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein the multi-grade engine oil meets the SAE 1300 standards as revised in January 2009.

In some embodiments, the present invention is directed to a multi-grade engine oil, having: a) a viscosity index between about 140-200; b) a kinematic viscosity at 100°C between about 6-10 cSt; c) a Pour Point less than about −30°C; and d) a Noack volatility of less than about 15 wt%, wherein the multi-grade engine oil is a 0W-SAE grade with a CCS Viscosity at −35°C less than about 6200 cP or the multi-grade engine oil is a 5W-SAE grade with a CCS Viscosity at −30°C less than about 6600 cP.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein the kinematic viscosity of the multi-grade engine oil at a temperature of 100°C is between about 3 to 10 centistokes.

In some embodiments, the present invention is directed to a multi-grade engine oil, wherein the CCS Viscosity at −30°C less than about 6,600 cP.
70% of the lubricant compositions. Lubricant compositions comprise a base oil and at least one additive. Lubricant compositions can be used in automobiles, diesel engines, axles, transmissions, and industrial applications. Lubricant compositions must meet the specifications for their intended application as defined by the concerned governing organization.

**[0037]** Additives, which can be blended with the base oil, to provide a lubricant composition include those which are intended to improve select properties of the lubricant composition. Typical additives include, for example, anti-wear additives, extreme pressure agents, detergents (e.g., metal-containing detergents), dispersants (e.g., ashless dispersants), antioxidants, pour point depressants, VI Improvers (VII), viscosity modifiers, friction modifiers, demulsifiers, antifoaming agents, inhibitors (e.g., corrosion inhibitors, rust inhibitors, etc.), seal swell agents, emulsifiers, wetting agents, lubricity improvers, metal deactivators, gelling agents, tackiness agents, bactericides, fluid-loss additives, colorants, and the like. Additives can be added in the form of an additive package, containing various additives.

**[0038]** Dispersants:

**[0039]** Dispersants are generally used to maintain in suspension insoluble materials resulting from oxidation during use, therefore sludging flocculation and precipitation or deposition on engine parts. Examples of dispersants include nitrogen-containing ashless (metal-free) dispersants. An ashless dispersant generally comprises an oil soluble polymeric hydrocarbon backbone having functional groups that are capable of associating with particles to be dispersed. Other examples of dispersants include, but are not limited to, amines, alcohols, amides, or ester polar moieties attached to the polymer backbone via bridging groups.

**[0040]** An ashless dispersant may be selected from oil soluble salts, esters, amino-esters, amides, imides, and oxazolines of long chain hydrocarbon substituted mono and dicarboxylic acids or their anhydrides; thiocarboxylate derivatives of long chain hydrocarbons, long chain aliphatic hydrocarbons having a polyamine attached directly thereto; and Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and polyalkylene polyamine Carboxylic dispersants are reaction products of carboxylic acylating agents (acids, anhydrides, esters, etc.) comprising at least 54 and preferably at least 54 carbon atoms with nitrogen containing compounds (such as amines), organic hydroxy compounds (such as aliphatic compounds including monohydric and polyhydric alcohols, or aromatic compounds including phenols and naphthols), and/or basic inorganic materials. These reaction products include imides, amides, and esters, e.g., succinimide dispersants.

**[0041]** Other suitable ashless dispersants may also include amine dispersants, which are reaction products of relatively high molecular weight aliphatic halides and amines, preferably polyalkylene polyamines. Other examples may further include “Mannich dispersants,” which are reaction products of alkyl phenols in which the alkyl group contains at least 30 carbon atoms with aldehydes (especially formaldehyde) and amines (especially polyalkylene polyamines). Furthermore, ashless dispersants may even include post-treated dispersants, which are obtained by reacting carboxylic, amine or Mannich dispersants with reagents such as dimercaptanethioles, urea, thiourea, carbon disulfide, aldehydes, ketones, carboxylic acids, hydrocarbon-substituted succinic anhydrides, nitrile epoxides, boron compounds and the like. Suitable ashless dispersants may be polymeric, which are interpolymer of oil-solubilizing monomers such as decyl methacrylate, vinyl decyl ether and high molecular weight olefins with monomers containing polar substituents. Other suitable ashless dispersants may also include an ethylene carbonate-treate bissuccininide derived from a polyisobutylene having a number average molecular weight of about 2300 Daltons (“PIBSA 2300”).

**[0042]** Viscosity Index Improvers (Modifiers):

**[0043]** The viscosity index of an engine oil base stock can be increased, or improved, by incorporating therein certain polymeric materials that function as viscosity modifiers (VM) or viscosity index improvers (VII) in an amount of 0.5 to 25 wt % of the final weight of the engine oil. Examples include but are not limited to olefin copolymers, such as ethylene-propylene copolymers, styrene-isoprene copolymers, hydrated styrene-isoprene copolymers, polybutene polyisobutylene, polyetherketones, vinylpyrrolidone and methacrylate copolymers and dispersant type viscosity index improvers. These viscosity modifiers can optionally be grafted with grafting materials such as, for example, maleic anhydride, and the grafted material can be reacted with, for example, amines, amides, nitrogen-containing heterocyclic compounds or alcohol, to form multifunctional viscosity modifiers (dispersant-viscosity modifiers).

**[0044]** Other examples of viscosity modifiers include star polymers (e.g., a star polymer comprising isoprene/styrene/isoprene triblock). Yet other examples of viscosity modifiers include poly (alkyl (meth)acrylates of low Brookfield viscosity and high shear stability, functionalized poly (alkyl (meth)acrylates with dispersant properties of high Brookfield viscosity and high shear stability, polyisobutylene having a weight average molecular weight ranging from 700 to 2,500 Daltons and mixtures thereof.

**[0045]** Friction Modifiers:

**[0046]** The lubricating oil composition may comprise at least a friction modifier (e.g., a sulfur-containing molybdenum compound). Certain sulfur-containing organo-molybdenum compounds are known to modify friction in lubricating oil compositions, while also offering antioxidant and anti-wear credits. Examples of oil soluble organo-molybdenum compounds include molybdenum succinimide complex, dithiocarbamates, diethosphates, diethosphorates, xanthates, thiooxanates, sulfides, and the like, and mixtures thereof.

**[0047]** Other examples include at least a mono-, di- or triester of a tertiary hydroxyl amine and a fatty acid as a friction modifying fuel economy additive. Other examples are selected from the group of succinimide acid, succinimide, and mixtures thereof. Other examples are selected from an aliphatic fatty amine, an ether amine, an alkoxylated aliphatic fatty amine, an alkoxylated ether amine, an oil-soluble aliphatic carboxylic acid, a polyol ester, a fatty acid amide, an imidazole, a tertiary amine, a hydrocarbyl succinic anhydride or acid reacted with an amonia or a primary amine, and mixtures thereof.

**[0048]** Seal Swelling Agents:

**[0049]** Seal fixes are also termed seal swelling agents or seal pacifiers. They are often employed in lubricant or additive compositions to insure proper elastomer sealing, and prevent premature seal failures and leakages. Seal swell agents may be selected from oil-soluble, saturated, aliphatic, or aromatic hydrocarbon esters such as di-2-ethylhexylphthalate, mineral oils with aliphatic alcohols such as tridecyl...
alcohol, triphosphate ester in combination with a hydrocarbonyl-substituted phenol, and di-2-ethylhexylsebacate.

[0050] Corrosion Inhibitors (Anti-Corrosive Agents):

[0051] These additives are typically added to reduce the degradation of the metallic parts contained in the engine oil in amounts from about 0.02 to 1 wt %. Examples include zinc dialkyldithiophosphate, phosphosulfurized hydrocarbons and the products obtained by reaction of a phosphosulfurized hydrocarbon with an alkaline earth metal oxide or hydroxide, preferably in the presence of an alkylated phenol or of an alkyphenol thiosteir. The rust inhibitor or anticorrosion agents may be a nonionic polyoxyethylene surface active agent. Nonionic polyoxyethylene surface active agents include, but are not limited to, polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonylphenyl ether, polyoxyethylene octylphenyl ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monooleate, polyoxyethylene sorbitol monooleate, and polyethylene glycol monooleate. Rust inhibitors or anticorrosion agents may also be other compounds, which include, for example, stearic and other fatty acids, dicarboxylic acids, metal soaps, fatty acid amine salts, metal salts of heavy sulfuric acid, partial carboxylic acid ester of polyhydric alcohols, and phosphoric esters. The rust inhibitor may be a calcium stearate salt.

[0052] Detergents:

[0053] In engine oil compositions, metal-containing or ash-forming detergents function both as detergents to reduce or remove deposits and as acid neutralizers or rust inhibitors, thereby reducing wear and corrosion and extending engine life. Detergents generally comprise a polar head with long hydrophobic tail, with the polar head comprising a metal salt of an acid organic compound.

[0054] The engine oil composition may contain one or more detergents, which are normally salts (e.g., overbased salts). Overbased salts, or overbased materials, are single phase, homogeneous Newtonian systems characterized by a metal content in excess of that which would be present according to the stoichiometry of the metal and the particular acidic organic compound reacted with the metal. The engine oil composition may comprise at least a carboxylate detergent. Carboxylate detergents, e.g., salicylates, can be prepared by reacting an aromatic carboxylic acid with an appropriate metal compound such as an oxide or hydroxide. The engine oil composition may comprise at least an overbased detergent. Examples of the overbased detergents include, but are not limited to, calcium sulfonates, calcium phenates, calcium salicylates, calcium stearates, and mixtures thereof. Overbased detergents may be low overbased (e.g., Total Base Number (TBN) below about 50). Suitable overbased detergents may alternatively be high overbased (e.g., TBN above about 150) or medium overbased (e.g., TBN between 50 and 150). The lubricating oil compositions may comprise more than one overbased detergent, which may be all low-TBN detergents, all high-TBN detergents, or a mix of those two types. Other suitable detergents for the lubricating oil compositions include “hybrid” detergents such as, for example, phenate/salicylates, sulfonate/phenates, sulfonate/salicylates, sulfonates/phenates/salicylates, and the like. The composition may comprise detergents made from alkyl benzene and fuming sulfuric acid, phenates (high overbased, medium overbased, or low overbased), high overbased phenate stearates, phenolates, salicylates, phosphonates, thiophosphates, sulfonates, carboxylates, ionic surfactants and sulfonates and the like.

[0055] Oxidation Inhibitors/Antioxidants:

[0056] Oxidation inhibitors or antioxidants reduce the tendency of mineral oils to deteriorate in service, which deterioration is evidenced by the products of oxidation such as sludge, lacquer, and varnish-like deposits on metal surfaces. The engine oil composition may contain from about 50 ppm to about 5.0 wt % of at least an antioxidant selected from the group of phenolic antioxidants, amine antioxidants, or a combination thereof. The amount of antioxidants may be between 0.10 to 3.00 wt %. The amount of antioxidants may be between about 0.20 to 0.80 wt %. An example of an antioxidant used is di-C8-diphenylamine, in an amount of about 0.05 to 2.00 wt % of the total weight of the oil composition. Other examples of antioxidants include MoS and Mo oxide compounds.

[0057] Other examples of antioxidants include hindered phenols; alkali earth metal salts of alkaldehydeoesters having C5 to C12 alkyl side chains; calcium nonylphenol sulphone; oil soluble phenates and sulfated phenates; phosphosulfurized or sulfonized hydrocarbons or esters; phosphorus esters; metal thiocarbamates; oil soluble copper compounds known in the art; phenyl naphthylamines such as phenylene diamine, phenothiazine, diphenylamine, diarylmethane; phenylalanaphthylamine, 2,2'-diethyl-4,4'-dicyclohexyl diphenylamine, 2,2'-diethyl-4-(1-octyl)-diphenylamine; alkaline earth metal salts of alkylphenol thioesters, having C5 to C12 alkyl side chains, e.g., calcium nonylphenol sulfide, barium t-octylphenol sulfide, zinc dialkyldithiophosphates, diocetylphenylamide, phenylalanaphthylamine and mixtures thereof. Some of these antioxidants further function as corrosion inhibitors. Other suitable antioxidants which also function as antiwear agents include bis alkyl dibithiothiazoles such as 2,5-bis-octyl dithiothiazole.

[0058] Anti-Foamants:

[0059] The engine oil may comprise an anti-foamant (foam inhibitor) in amounts ranging from about 5 to about 50 ppm. Examples include alkyl methacrylate polymers, dimethyl silicone polymers, and foam inhibitors of the polysiloxane type, e.g., silicone oil and polydimethyl silicone, for foam control. The anti-foamant may be a mixture of polydimethylsiloxane and fluorosilicone. Another example of an anti-foamant may be an acrylate polymer anti-foamant, with a weight ratio of the fluorosilicone anti-foamant to the acrylate anti-foamant ranging from about 3:1 to about 1:4. Another example of an anti-foamant may be an anti-foam-effective amount of a silicon-containing anti-foamant such that the total amount of silicone in the engine oil is at least 30 ppm. The silicone-containing anti-foam agent may be selected from the group consisting of fluorosilicones, polydimethylsiloxane, phenyl-methyl polysiloxane, linear siloxanes, cyclic siloxanes, branched siloxanes, silicone polymers and copolymers, organo-silicone copolymers, and mixtures thereof.

[0060] Anti-Wear Agents:

[0061] Anti-wear agents can also be added to the engine oil composition. The composition may comprise at least an anti-wear agent selected from phosphates, phosphites, carbamates, esters, sulfur containing compounds, and molybdenum complexes. Other representative of suitable antiwear agents are zinc dialkyl dithiophosphate, zinc diisopropyl phosphate, Zn or Mo dithiocarbamates, phosphites, amine phosphates, borated succinimide, magnesium sulfonate, and mixtures
the make up of at least a dihydrocarbolyldithiophosphate metal as an antiwear and antioxidant agent in amounts of about 0.1 to about 10 wt%. The metal may be an alkali or alkaline earth metal, or aluminum, lead, tin, molybdenum, manganese, nickel or copper.

[0062] Extreme Pressure Agents:

[0063] The engine oil composition may comprise an extreme pressure agent. Examples include alkaline earth metal borated extreme pressure agents and alkali metal borated extreme pressure agents. Other examples include sulfurized olefins, zinc dialkyldithiophosphate (primary alkyl, secondary alkyl, and aryI type), di-phenyl sulfide, methyl tri-chlorostearate, chlorinated naphthalene, fluoroalkylpolysiloxane, lead naphthenate, neutralized or partially neutralized phosphates, di-thiophosphates, and sulfur-free phosphates.

[0064] Some of the above-mentioned additives can provide a multiplicity of effects; thus for example, a single additive may act as a dispersant as well as an oxidation inhibitor. These multifunctional additives are well-known. Furthermore, when the engine oil composition contains one or more of the above-mentioned additives, each additive is typically blended into the base oil in an amount that enables the additive to provide its desired function. It may be desirable, although not essential to prepare one or more additive concentrates comprising additives (concentrates sometimes being referred to as “additive packages”) whereby several additives can be added simultaneously to the oil to form the end oil composition. The final composition may employ from about 0.5 to about 30 wt% of the concentrate, the remaining being the oil of lubricating viscosity. The components can be blended in any order and can be blended as combinations of components.

DEFINITIONS AND TERMS

[0065] The following terms will be used throughout the specification and will have the following meanings unless otherwise indicated.

[0066] The phrase “Group I Base Oil” contain less than 90 percent saturates and/or greater than 0.03 percent sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the ASTM methods specified in Table E-1 of American Petroleum Institute Publication 1509.

[0067] The term “Group II Base Oil” refers to a base oil which contains greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and has a viscosity index greater than or equal to 80 and less than 120 using the ASTM methods specified in Table E-1 of American Petroleum Institute Publication 1509.

[0068] The term “Group II+ Base Oil” refers to a Group II base oil having a viscosity index greater than or equal to 110 and less than 120.

[0069] The term “Group III Base Oil” refers to a base oil which contains greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and has a viscosity index greater than or equal to 120 using the ASTM methods specified in Table E-1 of American Petroleum Institute Publication 1509.

[0070] The term “Fischer-Tropsch derived” means that the product, fraction, or feed originates from or is produced at some stage by a Fischer-Tropsch process.

[0071] The term “petroleum derived” means that the product, fraction, or feed originates from the vapor overhead streams from distilling petroleum crude and the residual fuels that are the non-vaporizable remaining portion. A source of the petroleum derived product, fraction, or feed can be from a gas field condensate.

[0072] The term “multi-grade engine oil” refers to an engine oil that has viscosity/temperature characteristics which fall within the limits of two different SAE numbers in SAE J300. The present invention is directed to the discovery that multi-grade engine oils meeting the specifications under SAE J300 as revised 2009, including the MRV viscosity specifications, may be prepared from Fischer-Tropsch base oils having a defined cycloparaffin functionality when they are blended with a pour point depressing base oil blending component and an additive package.

[0073] The term “light neutral base oil” refers to a base oil with a boiling range from about 700°F to about 800°F, a kinematic viscosity at 100°C from 4 cSt to about 5 cSt.

[0074] The term “medium neutral base oil” refers to a base oil with a boiling range from about 800°F to about 900°F, a kinematic viscosity at 100°C from 5 cSt to about 8 cSt.

[0075] Highly paraffinic waxes mean a wax having a high content of n-paraffins, generally greater than 40 wt%, but can be greater than 50 wt%, or even greater than 75 wt%, and less than 100 wt% or 99 wt%. Examples of highly paraffinic waxes include slack waxes, deoiled slack waxes, refined foot oils, waxy lubricant raffinates, n-paraffin waxes, NAO waxes, waxes produced in chemical plant processes, deoiled petroleum derived waxes, microcrystalline waxes, Fischer-Tropsch waxes, and mixtures thereof.

[0076] The term “derived from highly paraffinic wax” means that the product, fraction, or feed originates from or is produced at some stage from a highly paraffinic wax.

[0077] Aromatics means any hydrocarbonaceous compounds that contain at least one group of atoms that share an uninterrupted cloud of delocalized electrons, where the number of delocalized electrons in the group of atoms corresponds to a solution of the Huckel rule of 4n+2 (e.g., n=1 for 6 electrons, etc.). Representative examples include, but are not limited to, benzene, biphenyl, naphthalene, and the like.

[0078] Molecules with cycloparaffinic functionality mean any molecule that is, or contains as one or more substituents, a monocyclic or a fused multicyclic saturated hydrocarbon group. The cycloparaffinic group can be optionally substituted with one or more, such as one to three, substituents. Representative examples include, but are not limited to, cyclopentyl, cyclobutyl, cyclohexyl, cyclopentyl, cycloheptyl, decahydroquinophthalene, octahydroquinaldene, (pentadecan-6-y)cyclohexane, 3,7,10-tricyclohexylnentalcane, decahydro-1-(pentadecan-6-y)naphthalene, and the like.

[0079] Molecules with monocycloparaffinic functionality mean any molecule that is a monocyclic saturated hydrocarbon group of three to seven ring carbons or any molecule that is substituted with a single monocyclic saturated hydrocarbon group of three to seven ring carbons. The cycloparaffinic group can be optionally substituted with one or more, such as one to three, substituents. Representative examples include, but are not limited to, cyclopropyl, cyclobutyl, cyclohexyl, cyclopentyl, cycloheptyl, (pentadecan-6-y)cyclohexane, and the like.

[0080] Molecules with multicycloparaffinic functionality mean any molecule that is a fused multicyclic saturated hydrocarbon ring group of two or more fused rings, any molecule that is substituted with one or more fused multicyclic saturated hydrocarbon ring groups of two or more fused rings, or any molecule that is substituted with more than one
monocyclic saturated hydrocarbon group of three to seven ring carbons. The fused multicyclic saturated hydrocarbon ring group often is of two fused rings. The cyclopentane ring group can be optionally substituted with one or more, such as one to three, substituents. Representative examples include, but are not limited to, decahydropentaphenalen, octahydropentadecene, decaldehyde-1-(pentadecan-6-yl)pentaphenalen, and the like.

Brookfield Viscosity: ASTM D2983-04a is used to determine the low-shear-rate viscosity of automotive fluid lubricants at low temperatures. The low-temperature, low-shear-rate viscosity of automatic transmission fluids, gear oils, torque and tractor fluids, and industrial and automotive hydraulic oils are frequently specified by Brookfield viscosities.

Kinematic viscosity is a measurement of the resistance to flow of a fluid under gravity. Many base oils, lubricant compositions made from them, and the correct operation of equipment depends upon the appropriate viscosity of the fluid being used. Kinematic viscosity is determined by ASTM D445-06. The results are reported in mm²/s.

Viscosity index (VI) is an empirical, unitless number indicating the effect of temperature change on the kinematic viscosity of the oil. Viscosity index is determined by ASTM D2270-04.

Pour point is a measurement of the temperature at which a sample of base oil will begin to flow under carefully controlled conditions. Pour point can be determined as described in ASTM D5950-02. The results are reported in degrees Celsius. Many commercial base oils have specifications for pour point. When base oils have low pour points, the base oils are also likely to have other good low temperature properties, such as low cloud point, low cold filter plugging point, and low temperature cracking viscosity.

Noack volatility is usually tested according to ASTM D5800-05 Procedure B. A more convenient method for calculating Noack volatility and one which correlates well with ASTM D5800-05 is by using a thermogravimetric analyzer (TGA) test by ASTM D6375-05. TGA Noack volatility is used throughout the present disclosure unless otherwise stated.

The base oils of the lubricant composition as disclosed herein also have excellent viscometric properties under low temperature (i.e., cold flow properties) and high shear, making them very useful in multi-grade engine oils. The cold-cranking simulator apparent viscosity (CCS VIS) is a test used to measure the viscometric properties of base oils under low temperature and high shear. The test method to determine CCS VIS is ASTM D5293-02. Results are reported in mPas. CCS VIS has been found to correlate with low temperature engine cracking. Specifications for maximum CCS VIS are defined for automotive engine oils by SAE J300, revised in 2009. The maximum CCS VIS for a 0W SAE Viscosity Grade engine oil is 6200 mPas at -35°C.

The phrase "improving cold flow properties" refers to one or more of lowering CCS VIS (cold-cranking simulator apparent viscosity) at -25°C, -30°C or -35°C, lowering pour point and lowering Noack.

The Mini-Rotary Viscometer (MRV) test, ASTM D4684-07, which is related to the mechanism of pumpability, is a low shear rate measurement. Slow sample cooling rate is the method's key feature. A sample is pretreated to have a specified thermal history which includes warming, slow cooling, and soaking cycles. The MRV measures an apparent yield stress, which, if greater than a threshold value, indicates a potential air-binding pumping failure problem. Above a certain viscosity (currently defined as 60,000 mPas by SAE J300 2009), the oil may be subject to pumpability failure by a mechanism called "flow limited" behavior. An SAE 0W oil, for example, is required to have a maximum viscosity of 60,000 mPas at -40°C with no yield stress. This method also measures an apparent viscosity under shear rates of 1 to 50 s⁻¹.

High temperature high shear rate viscosity (HTHVS) is a measure of a fluid's resistance to flow under conditions resembling highly-loaded journal bearings in fired internal combustion engines, typically 1 million s⁻¹ at 150°C. HTHVS is a better indication of how an engine operates at high temperature with a given lubricant than the kinematic low shear rate viscosities at 100°C. The HTHVS value directly correlates to the oil film thickness in a bearing. SAE J300 2009 contains the current specifications for HTHVS measured by ASTM D4683, ASTM D4741, or ASTM D5481. An SAE 20 viscosity grade engine oil, for example, is required to have a minimum HTHVS of 2.6 mPas.

Scanning Brookfield Viscosity: ASTM D5133-05 is used to measure the low temperature, low shear rate, viscosity/temperature dependence of engine oils. The low temperature, low shear viscometric behavior of an engine oil determines whether the oil will flow to the sump inlet screen, then to the oil pump, then to the sites in the engine requiring lubrication in sufficient quantity to prevent engine damage immediately or ultimately after cold temperature starting. ASTM D5133-05, the Scanning Brookfield Viscosity technique, measures the Brookfield viscosity of a sample as it is cooled at a constant rate of 1°C/hour. Like the MRV, ASTM D5133-05 is intended to relate to the pumpability of an oil at low temperatures. The test reports the gelation point, defined as the temperature at which the sample reaches 30,000 mPas. The gelation index is also reported, and is defined as the largest rate of change of viscosity increase from -5°C to the lowest test temperature. The latest API SM/ILSAC GF-4 specifications for passenger car engine oils require a maximum gelation index of 12.

“Lubricants,” as defined herein, are substances (usually a fluid under operating conditions) introduced between two moving surfaces so to reduce the friction and wear between them. Base oils used as motor oils are generally classified by the American Petroleum Institute as being mineral oils (Group I, II, and III) or synthetic oils (Group IV and V). See American Petroleum Institute (API) Publication Number 1500.

“Pour point,” as defined herein, represents the lowest temperature at which a fluid will pour or flow. See, e.g., ASTM International Standard Test Methods D 5950-96, D 6892-03, and D 97.

“Cloud point,” as defined herein, represents the temperature at which a fluid begins to phase separate due to crystal formation. See, e.g., ASTM Standard Test Methods D 5773-95, D 2500, D 5551, and D 5771.

“Centistokes,” abbreviated “cSt,” is a unit for kinematic viscosity of a fluid (e.g., a lubricant), wherein 1 centistoke equals 1 millimeter squared per second (1 cSt = 1 mm²/s). See, e.g., ASTM Standard Guide and Test Methods D 2270-04, D 445-06, D 6074, and D 2983.

With respect to describing molecules and/or molecular fragments herein, “R,” where “n” is an index,
refers to a hydrocarbon group, wherein the molecules and/or molecular fragments can be linear and/or branched.

0096. As defined herein, “Cₙ,” where “n” is an integer, describes a hydrocarbon molecule or fragment (e.g., an alkyl group) wherein “n” denotes the number of carbon atoms in the fragment or molecule.

0097. The prefix “bio,” as used herein, refers to an association with a renewable resource of biological origin, such as resource generally being exclusive of fossil fuels.

0098. The term “internal olefin,” as used herein, refers to an olefin (i.e., an alkene) having a non-terminal carbon-carbon double bond (C—C). This is in contrast to “endolefins” which do bear a terminal carbon-carbon double bond.

0099. The terms Yubase 4 and Yubase 6 are base oils defined as presented in Table 1 shown below.

### TABLE 1

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>YUBASE 4</th>
<th>YUBASE 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Visual</td>
<td>Bright &amp; Clear</td>
<td>Bright &amp; Clear</td>
</tr>
<tr>
<td>Specific Gravity, @154°C</td>
<td>ASTM D 1298</td>
<td>0.8338</td>
<td>0.8423</td>
</tr>
<tr>
<td>Kinematic Viscosity, @40°C</td>
<td>ASTM D 445</td>
<td>19.57</td>
<td>36.82</td>
</tr>
<tr>
<td>Kinematic Viscosity, @100°C</td>
<td>ASTM D 445</td>
<td>4.23</td>
<td>6.52</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>ASTM D 2270</td>
<td>122</td>
<td>131</td>
</tr>
<tr>
<td>Noack Volatility, wt %</td>
<td>DIN 51581</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Flash Point, °C</td>
<td>ASTM D 92</td>
<td>230</td>
<td>240</td>
</tr>
<tr>
<td>Pour Point, °C</td>
<td>ASTM D 97</td>
<td>-15</td>
<td>-15</td>
</tr>
<tr>
<td>Color</td>
<td>ASTM D 1500</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>Carbon Residue, wt %</td>
<td>ASTM D 189</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Copper Corrosion</td>
<td>ASTM D 130</td>
<td>1-a</td>
<td>1-a</td>
</tr>
<tr>
<td>Sulfur, ppm</td>
<td>ASTM D 2622</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Total Acid No., mgKOH/g</td>
<td>ASTM D 664</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

0100. The terms “100R, 150R, 220R, 600R and 110RLV” are base oils defined as presented in Table 2 shown below.

### TABLE 2

<table>
<thead>
<tr>
<th>Property</th>
<th>ASTM Method</th>
<th>100R</th>
<th>150R</th>
<th>220R</th>
<th>600R</th>
<th>110RLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Base Oil Category</td>
<td>API 1509 E 1.3</td>
<td>II Bright and Clear</td>
<td>II Bright and Clear</td>
<td>II Bright and Clear</td>
<td>II Bright and Clear</td>
<td>II Bright and Clear</td>
</tr>
<tr>
<td>Appearance</td>
<td>SM 360-99</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Color</td>
<td>ASTM D 1500</td>
<td>34.4</td>
<td>33.4</td>
<td>31.9</td>
<td>31.2</td>
<td>35.4</td>
</tr>
<tr>
<td>API Gravity, deg.</td>
<td>ASTM D 4052</td>
<td>7.1</td>
<td>7.15</td>
<td>7.22</td>
<td>7.28</td>
<td>7.06</td>
</tr>
<tr>
<td>Density, lb/gal</td>
<td>ASTM D 4052</td>
<td>0.853</td>
<td>0.858</td>
<td>0.867</td>
<td>0.874</td>
<td>0.848</td>
</tr>
<tr>
<td>Density, kg/l</td>
<td>ASTM D 4052</td>
<td>0.853</td>
<td>0.858</td>
<td>0.867</td>
<td>0.874</td>
<td>0.848</td>
</tr>
<tr>
<td>Specific Gravity, @60° F</td>
<td>ASTM D 445</td>
<td>20.3</td>
<td>30.9</td>
<td>43.7</td>
<td>108</td>
<td>21.1</td>
</tr>
<tr>
<td>Viscosity @40°C, cSt</td>
<td>ASTM D 445</td>
<td>4.1</td>
<td>5.3</td>
<td>6.6</td>
<td>12.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Viscosity @100° F, SUS</td>
<td>ASTM D 2161</td>
<td>107</td>
<td>153</td>
<td>214</td>
<td>590</td>
<td>113</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>ASTM D 2270</td>
<td>102</td>
<td>107</td>
<td>102</td>
<td>103</td>
<td>118</td>
</tr>
<tr>
<td>CCS @20°C, cP</td>
<td>ASTM D 5293</td>
<td>N/A</td>
<td>1750</td>
<td>3400</td>
<td>N/A</td>
<td>822</td>
</tr>
<tr>
<td>CCS @25°C, cP</td>
<td>ASTM D 5293</td>
<td>1400</td>
<td>2660</td>
<td>5600</td>
<td>N/A</td>
<td>1350</td>
</tr>
<tr>
<td>CCS @30°C, cP</td>
<td>ASTM D 5293</td>
<td>2650</td>
<td>5070</td>
<td>N/A</td>
<td>N/A</td>
<td>2450</td>
</tr>
<tr>
<td>Pour Point, °C</td>
<td>ASTM D 5950/1C</td>
<td>-15</td>
<td>-15</td>
<td>-13</td>
<td>-17</td>
<td>-15</td>
</tr>
<tr>
<td>Flash Point, °COC, °C</td>
<td>ASTM D 92</td>
<td>206</td>
<td>227</td>
<td>230</td>
<td>270</td>
<td>216</td>
</tr>
<tr>
<td>Volatility, wt % distilled at 700° F/371° C</td>
<td>ASTM D 2887</td>
<td>13</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Evaporative Loss, NOACK, wt %</td>
<td>ASTM D5800 (B)</td>
<td>26</td>
<td>14</td>
<td>10</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Water, ppm</td>
<td>ASTM D 6304-98</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Sulfur, ppm</td>
<td>ICP/XRF</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;6</td>
</tr>
<tr>
<td>Saturates, HPLC wt %</td>
<td>Chevron</td>
<td>&gt;99</td>
<td>&gt;99</td>
<td>&gt;99</td>
<td>&gt;99</td>
<td>&gt;99</td>
</tr>
<tr>
<td>Aromatics, HPLC wt %</td>
<td>Chevron</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

[0101] Unless otherwise indicated herein, scientific and technical terms used in connection with the present invention shall have the meanings that are commonly understood by those of ordinary skill in the art. Further, unless otherwise required by context, singular terms shall include pluralities and plural terms shall include the singular. More specifically, as used in this specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a fatty acid” includes a plurality of fatty acids, and the like. In addition, ranges provided in the specification and appended claims include both end points and all points between the end points. Therefore, a range of 2.0 to 3.0 includes 2.0, 3.0 and all points between 2.0 and 3.0. Furthermore, 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". 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. As used herein, the term “comprising” means including elements or steps that are identified following that term, but any such elements or steps are not exhaustive, and an embodiment can include other elements or steps.

**EXAMPLES**

[0102] The following examples are provided to demonstrate particular embodiments of the present invention. It should be appreciated by those of skill in the art that the methods disclosed in the examples which follow merely represent exemplary embodiments of the present invention. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments described and still obtain a like or similar result without departing from the spirit and scope of the present invention.
Example 1

This example serves to illustrate the base oil blends with and without the diesters of the present invention with the analytics presented in Table 3 below.

Example 2

This example serves to illustrate the base oil blends with the diesters of the present invention, a single comparative without diester and a second comparative with a commercially available ester (i.e., Esterex A51) with the analytics presented in Table 4 below. Diester A is a diester of Formula I, wherein R₁ and R₂ are combined to have a carbon number of C₁₂ and R₃ and R₄ are both C₁₃. Diester B2 is a diester of Formula I, wherein R₁ and R₂ are combined to have a carbon number of C₁₂ and R₃ and R₄ are both independently C₆-C₁₀. The examples in Table 3 were prepared in a similar manner as those of Example 1 herein.

Example 3

This example serves to illustrate the diesters prepared and their respective properties as presented in Table 5.

### Table 3-continued

<table>
<thead>
<tr>
<th>Base Oil Blend</th>
<th>Example 1</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>API</td>
</tr>
<tr>
<td></td>
<td></td>
<td>@ 100° C., cSt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Viscosity, cSt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pour point, °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cloud point, °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Noack, wt %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CCS @ -35° C., cP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bromine number</td>
</tr>
</tbody>
</table>

### Table 4

<table>
<thead>
<tr>
<th>Composition, wt %</th>
<th>BOBO2958</th>
<th>BOBO2959</th>
<th>BOBO2960</th>
<th>BOBO2961</th>
</tr>
</thead>
<tbody>
<tr>
<td>110RLV</td>
<td>52.43</td>
<td>59.31</td>
<td>59.25</td>
<td>59.16</td>
</tr>
<tr>
<td>100R</td>
<td>13.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>220R</td>
<td>34.56</td>
<td>35.55</td>
<td>35.51</td>
<td>35.46</td>
</tr>
<tr>
<td>Diester A</td>
<td>5.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diester B2</td>
<td></td>
<td>5.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esterex A51</td>
<td></td>
<td></td>
<td></td>
<td>5.37</td>
</tr>
</tbody>
</table>

### Table 5

<table>
<thead>
<tr>
<th>Starting Materials</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Olefin</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>C14</td>
</tr>
<tr>
<td>B</td>
<td>C14</td>
</tr>
<tr>
<td>C</td>
<td>C14</td>
</tr>
<tr>
<td>D</td>
<td>C16</td>
</tr>
<tr>
<td>E</td>
<td>C18</td>
</tr>
</tbody>
</table>
Example 4

This example serves to illustrate the Noack and CCS Viscosity of the diesters of the present invention as compared to the current commercial esters and other Group II and III base oils as presented in Table 6 and FIG. 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>CCS (25°)</th>
<th>CCS (30°)</th>
<th>Noack</th>
<th>KV100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diester A</td>
<td>542</td>
<td>812</td>
<td>8.9</td>
<td>4.76</td>
</tr>
<tr>
<td>Diester B2</td>
<td>1002</td>
<td>1717</td>
<td>9.1</td>
<td>4.19</td>
</tr>
<tr>
<td>Diester D2</td>
<td>7118</td>
<td>1875</td>
<td>6.3</td>
<td>4.354</td>
</tr>
<tr>
<td>Estere A51</td>
<td>1958</td>
<td>2487</td>
<td>7.4</td>
<td>5.4</td>
</tr>
<tr>
<td>Estere A32</td>
<td>212</td>
<td>319</td>
<td>30.3</td>
<td>2.8</td>
</tr>
</tbody>
</table>

All patents, patent applications and publications are herein incorporated by reference to the same extent as if each individual patent, patent application or publication was specifically and individually indicated to be incorporated by reference.

The present invention if not to be limited in scope by the specific embodiments described herein, which are intended as single illustrations of individual aspects of the invention, and functionally equivalent methods and components are within the scope of the invention. Indeed, various modifications of the invention, in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. A multi-grade engine oil comprising:
   a) a diester component, comprising a quantity of at least one diester species having the following structure:

   ![Diester Structure](image)

   wherein R1, R2, R3, and R4 are the same or independently selected from C2 to C13 hydrocarbon groups;
   b) a second base oil; and
   c) an additive package,

   wherein the second base and third base oil are independently selected from the group consisting of Group I base oil, Group II base oil or Group III base oil.

2. The multi-grade engine oil of claim 1, wherein a quantity of at least one diester species comprises a mixture of isomers where R1 and R2 are different for each isomer.

3. The multi-grade engine oil of claim 1, further comprising, a third base oil.

4. The multi-grade engine oil of claim 1, wherein the diester has a Noack Volatility between about 6 and 10 wt., a CCS Viscosity at −30°C between about 700 and 2000 cP, a pour point less than about −10°C, a cloud point less than about −16°C, a kinematic viscosity at 100°C between about 2.5 to 6.5 centistokes, a VI greater than about 110 and a BN Oxidator greater than about 20 hours.

5. The multi-grade engine oil according to claim 1 or 3, wherein the second base and third base oil are independently selected from the group consisting of light neutral base oil, medium neutral base oil, Yubase 4, Yubase 6, 150R, 600R, 110R/LV, 220R and 100R.

6. The multi-grade engine oil of claim 1, meeting the specifications for SAE viscosity grade 0W-XX or 5W-XX, wherein XX represents the integer 16, 20, 30, or 40.

7. The multi-grade engine oil of claim 1, wherein the multi-grade engine oil meets the SAE 3300 standards as revised in January 2009.

8. The multi-grade engine oil of claim 1, having:
   a) a viscosity index about 140-200;
   b) a kinematic viscosity at 100°C between about 6-10 cSt;
   c) a Pour Point less than about −30°C; and
   d) a Noack volatility of less than about 15 wt.%,

   wherein the multi-grade engine oil is a 0W-SAE grade with a CCS Viscosity at −35°C less than about 6200 cP or the multi-grade engine oil is a 5W-SAE grade with a CCS Viscosity at −30°C less than about 6600 cP.

9. The multi-grade engine oil of claim 1, wherein the kinematic viscosity of the multi-grade engine oil at a temperature of 100°C is between about 3 to 10 centistokes.

10. The multi-grade engine oil of claim 1, wherein the CCS Viscosity at −30°C is less than about 6,600 cP.

11. The multi-grade engine oil of claim 1, wherein the CCS Viscosity at −35°C is less than about 6,200 cP.

12. The multi-grade engine oil of claim 1, wherein the Noack Volatility is less than about 15 wt.%,

13. The multi-grade engine oil of claim 1, wherein R1 and R2 are selected to have a combined carbon number of from 6 to 16 and R3 and R4 are selected to have a combined carbon number of from 10 to 34.

14. The multi-grade engine oil of claim 1, wherein R1 and R2 of Formula I are selected to have a combined carbon number of C18-C4 or C12 and R3 and R4 are independently selected from the group consisting of C18 and a mixture of C8-C10.
15. The multi-grade engine oil of claim 1, wherein the at least one diester species is derived from a C₆ to C₁₈ olefin and a C₆ to C₁₄ carboxylic acid.

16. The multi-grade engine oil of claim 2, wherein said composition comprises quantities of at least two different diester isomers.

17. The multi-grade engine oil of claim 1, wherein the at least one diester species has a molecular mass that is from at least about 340 a.m.u. to at most about 780 a.m.u.

18. The multi-grade engine oil of claim 1, wherein the at least one diester species is selected from the group consisting of decanoic acid 2-decanoyloxy-1-hexyl-octyl ester and its isomers, tetradecanoic acid 1-hexyl-2-tetradecanoyloxy-octyl esters and its isomers, dodecanoic acid 2-dodecanoyloxy-1-hexyl-octyl ester and its isomers, hexanoic acid 2-hexanoyloxy-1-hexyl-octyl ester and its isomers, octanoic acid 2-octanoyloxy-1-hexyl-octyl ester and its isomers, hexanoic acid 2-hexanoyloxy-1-pentyl-heptyl ester and isomers, octanoic acid 2-octanoyloxy-1-pentyl-heptyl ester and isomers, decanoic acid 2-decanoyloxy-1-pentyl-heptyl ester and isomers, dodecanoic acid 2-dodecanoyloxy-1-pentyl-heptyl ester and isomers, tetradecanoic acid 1-pentyly-2-tetradecanoyloxy-heptyl ester and isomers, tetradecanoic acid 1-butyl-2-tetradecanoyloxy-hexyl ester and isomers, dodecanoic acid 1-butyl-2-dodecanoyloxy-hexyl ester and isomers, dodecanoic acid 1-butyl-2-decanoyloxy-hexyl ester and isomers, octanoic acid 1-butyl-2-octanoyloxy-hexyl ester and isomers, hexanoic acid 1-butyl-2-hexanoyloxy-hexyl ester and isomers, tetradecanoic acid 1-propyl-2-tetradecanoyloxy-pentyl ester and isomers, dodecanoic acid 2-dodecanoyloxy-1-propyl-pentyl ester and isomers, decanoic acid 2-decanoyloxy-1-propyl-pentyl ester and isomers, hexanoic acid 2-hexanoyloxy-1-propyl-pentyl ester and isomers, and mixtures thereof.

19. The multi-grade engine oil of claim 1, wherein the multi-grade engine oil is formulated as a 0W-20 SAE 0W-16 or 5W-20 SAE engine oil.

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