LUBRICANT COMPOSITION CONTAINING ETHYLENE-ALPHA OLEFIN COPOLYMER VISCOSITY MODIFIER

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ABSTRACT

Provided are lubricant compositions containing ethylene/\alpha-olefin copolymer viscosity modifiers which impart unique viscometrics in high VI/low aromatics base stocks for engine oil applications. In one form, the lubricant compositions include a blend of Group I to Group V base stocks, or mixtures thereof, and an ethylene/\alpha-olefin copolymer made from ethylene with one or more \alpha-olefin, wherein the \alpha-olefin has from 3 to 18 carbon atoms and the ethylene/\alpha-olefin copolymer has a number average molecular weight between 800 and 20,000 and a molecular weight distribution of less than 3.0.
FIGURE 1

\[ y = 2.5858 \ln(x) - 2.6738 \]
LUBRICANT COMPOSITION CONTAINING ETHYLENE-ALPHA OLEFIN COPOLYMER VISCOSITY MODIFIER

FIELD

[0001] This disclosure relates to lubricant compositions containing ethylene/α-olefin copolymer viscosity modifiers which impart unique viscometrics in high VI/low aromatics base stocks for engine oil applications.

BACKGROUND

[0002] Multi-grade engine oils, derived from a combination of low viscosity basestocks and high molecular weight thickeners, viscosity index improvers, and other components have been used for a long time. Synthetic engine oils based on polyalphaolefins (PAOs) have been shown to demonstrate performance benefits together with cost effectiveness in automotive and other engine applications. In these synthetic oils, as with conventional oils of mineral origin, the viscosity-temperature relationship of the oil is one of the critical criteria which must be considered when selecting the lubricant for a particular application. The viscosity requirements for qualifications as multi-grade engine oils are described by the SAE Engine Oil Viscosity Classification-SAE J300.

[0003] The low temperature (W) viscosity requirements are determined by two tests, 1. ASTM D5293, Method of Test for Apparent Viscosity of Motor Oils at Low Temperature Using the Cold Cranking Simulator (CCS), and 2. ASTM D4683, Standard Test Method for Determination of Yield Stress and Apparent Viscosity of Engine Oils at Low Temperature. Higher temperature viscosity is measured according to 1. ASTM D445 (at 100 °C), Method of Testing for Kinematic Viscosity of Transparent and Opaque Liquids, and 2. ASTM D4683 (at 150 °C), Standard Test Method for Measuring Viscosity at High Shear Rate and High Temperature by Tapered Bearing Simulator. Table 1 outlines the high and low temperature requirements for the recognized SAE grades for engine oils.

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE VISCOSITY GRADES FOR engine OILS (cP) (2) (S.AE MOO, Revised May 2004)</td>
</tr>
</tbody>
</table>

[0004] [0005] [0006] [0007] [0008] [0009] [0010] [0011] [0012] [0013] [0014]
D4683. This is required for bearing protection in engines which are capable of high power output under high load conditions.

[0015] However, for lower viscosity multigrade oils (as defined by the SAE J300-99 standard), formulating oils with an HTHS viscosity of 3.5 cP minimum typically results in kinematic viscosity at 100°C (KV100) very close to the upper limit for certain viscosity grades. For example, an SAE 0W-30 or 5W-30 oil with an HTHS viscosity of 3.5 cP will typically have a KV100 of 12 cSt or higher, while the KV100 specification for SAE 30 ranges from 9.3 cSt minimum to 12.5 cSt maximum.

[0016] Various combinations of additives with lubricants have been used in the past for the improvement of lubricant properties and in particular, the use of polymeric materials for altering the viscosity or viscosity index of base stocks of mineral and synthetic origin has been well known for a number of years. Polymeric thickeners which are commonly used in the production of multi-grade lubricants typically include hydrogenated styrene-isoprene block copolymers, rubbers based on ethylene and propylene, polymers produced by polymerization of esters of the acrylate or methacrylate series, polyisobutylene and the like. These polymeric thickeners are added to bring the viscosity of the base fluid up to the level required for the desired grade (high temperature specification) and possibly to increase the viscosity index of the fluid, allowing for the production of multi-grade oils.

[0017] The use of high molecular weight thickeners and VI improvers in the production of multi-grade lubricants has, however, some serious drawbacks. First, these improvements are more sensitive to oxidation than the base stocks in which they are used, which may result in a progressive loss of viscosity index and thickening power with use and frequently in the formation of unwanted deposits. In addition, these materials tend to be sensitive to high shear rates and stresses which can result in temporary or permanent viscosity losses, or reduction of film thickness in bearings. Temporary viscosity losses occurring from shear forces are the result of the non-Newtonian viscometries associated with the solutions of high molecular weight polymers. As the polymer chains align with the shear field under high shear rates, a decrease in viscosity occurs, reducing film thickness and the wear protection associated with the elastohydrodynamic film. By contrast, Newtonian fluids maintain their viscosity regardless of shear rate. From the point of view of lubricant performance at high temperatures and under the influence of a shear rate condition, it would be desirable to maintain Newtonian rheological properties for the lubricant. High molecular weight thickeners are susceptible to temporary or permanent shear thinning at high shear rate, resulting in loss of viscosity under low or high temperature conditions. Excessive shear thinning or loss of viscosity is undesirable in certain applications such as bearings which rely primarily on oil film thickness for protection.

[0018] U.S. Pat. No. 6,713,438, incorporated by reference herein in its entirety, discloses high performance engine oils comprising a blend of a low viscosity, liquid lubricant base stock with two dissolved polymer components of different molecular weights. The lower molecular weight polymer is highly viscoelastic in character and is preferably an HVI PAO. The use of the highly viscoelastic low molecular weight polymer in combination with the higher molecular weight thickener enables the production of very widely cross-graded engine oils, especially oils with a low temperature grading of 0W or better.

[0019] U.S. Pat. No. 7,022,784, incorporated by reference herein in its entirety, discloses a liquid polymer suitable for use as a lubricant base oil, which is produced by polymerizing ethylene and at least one alpha-olefin using a metalloocene catalyst to provide a polymer which is then isomerized and hydrogenated to produce the liquid polymer.

[0020] U.S. Published Patent Application No. 2003/0236177 A1, incorporated by reference herein in its entirety, discloses a fluid blend suitable for use as a lube base stock comprises two major components: (A) a copolymer made from ethylene with one or more alpha olefins, the copolymer (i) containing not more than 50 wt % ethylene; (ii) having a number average molecular weight of from 400 to 10,000; and (iii) a molecular weight distribution <3; and (B) a polyalphaolefin fluid or a hydropyrolyzed oil having a VI greater than 80.

**SUMMARY**

[0021] A first embodiment of the present disclosure is directed to a lubricant composition comprising a blend of Group I to Group VI base stocks, or mixtures thereof, and an ethylene-α-olefin copolymer made from ethylene with one or more α-olefin, wherein the α-olefin has from 3 to 18 carbon atoms and the ethylene/α-olefin copolymer has a number average molecular weight between 800 and 20,000 and a molecular weight distribution of less than 3.0.

[0022] In another embodiment, the copolymer of the lubricant composition can comprise between 10 wt % and 45 wt % ethylene content.

[0023] In another embodiment, the lubricant composition can comprise between 1 wt % to 20 wt % of the ethylene/α-olefin copolymer.

[0024] In another embodiment, the lubricant composition can comprise between 2 to 15% of the ethylene/α-olefin copolymer.

[0025] In another embodiment, the copolymer of the lubricant composition has a number average molecular weight ranging from 2000 to 10,000.

[0026] In another embodiment, the copolymer of the lubricant composition has a number average molecular weight ranging from 3000 to 8000.

[0027] In another embodiment, the copolymer of the lubricant composition has a number average molecular weight ranging from 3000 to 6000.

[0028] Conventionally, the copolymer is made with metalloocene catalysts.

[0029] In another embodiment the lubricant composition base stock is a Group III base stock.

[0030] In another embodiment the lubricant composition base stock is a Group IV base stock.

[0031] In another embodiment the lubricant composition base stock is a Group V base stock.

[0032] In another embodiment the lubricant composition base stock is a Gas to Liquid (GTL) derived base stock.

[0033] In another embodiment the lubricant composition base stock is a mixture selected from one or more of a Group III base stock, Group IV base stock, Group V base stock and GTL base stock.

[0034] In another embodiment, the ethylene/α-olefin copolymer is a liquid ethylene/1-butene copolymer.
In another embodiment, the ethylene/α-olefin copolymer has a molecular weight distribution of less than 2.5.

In another embodiment, the ethylene/α-olefin copolymer has a molecular weight distribution of less than 2.0.

In another embodiment, the lubricant composition has a high temperature shear viscosity (HTHIS) according to ASTM D4683 of higher than 2.58585 Ln(100°C) K. V. in cP> 2.6738.

In another embodiment, the lubricant composition has a high temperature shear viscosity (HTHIS) according to ASTM D4683 of at least 3.5 cP and a mini rotary viscosity (MRV) at 40°C. according to ASTM D4684 of less than 15,000 cP.

In another embodiment, the lubricant composition has a MRV viscosity at 40°C. less than 1.838.8xc^10^0.592xmr (HTHIS viscosity at 2P).

In another embodiment, the lubricant composition has a high temperature shear viscosity (HTHIS) according to ASTM D4683 of at least 2.9 cP and a mini rotary viscosity (MRV) at 40°C. according to ASTM D4684 of less than 1.838.8x10^-0.592xmr (HTHIS viscosity at 2P).

In another embodiment, the lubricant composition has a high temperature shear viscosity (HTHIS) according to ASTM D4683 of at least 2.9 cP and a mini rotary viscosity (MRV) at 40°C. according to ASTM D4684 of less than 26,000 cP.

In another embodiment, the lubricant composition has an HTHIS of at least 2.6 cP and a kinematic viscosity at 100°C. of less than 16 cSt.

In another embodiment, the copolymer of the lubricant composition comprises between about 19 wt% and 45 wt% ethylene content, has a number average molecular weight between about 2000 and about 6,000 and a molecular weight distribution of less than about 2.5.

In another embodiment, the lubricant composition further comprises lubricant additives selected from the group consisting of viscosity index improvers, corrosion inhibitors, dispersants, oxidation inhibitors, detergents, rust inhibitors, antiwear agents, anti-foaming agents, flow improvers, friction modifiers, and seal swellants.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph of HTHIS viscosity vs. 100°C. K. V for formulated lubricants.

FIG. 2 is a graph of MRV at 40°C. vs. HTHIS Viscosity for formulated lubricants.

DETAILED DESCRIPTION

All numerical values in this disclosure are understood as being modified by “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

European engine builders recommend oils which have a minimum high temperature shear viscosity (HTHIS) of 3.5 cP measured according to ASTM D4683. This is required for bearing protection in engines which are capable of high power output under high load conditions.

However, for lower viscosity multigrade oils (as defined by the SAE J300-99 standard), formulating oils with an HTHIS viscosity of 3.5 cP minimum typically results in kinematic viscosity at 100°C. (KV100) very close to the upper limit for certain viscosity grades. For example, an SAE 0W-30 or 5W-30 oil with an HTHIS viscosity of 3.5 cP will typically have a KV100 of 12 cSt or higher, while the KV100 specification for SAE 30 ranges from 9.3 cSt minimum to 12.5 cSt maximum.

Another important characteristic for low viscosity engine oils is low temperature pumpability, typically measured by the MRV (mini rotary viscosity) test of ASTM D4684. The results of this test are often reported in cP as measured at -40°C. The maximum MRV for a 0W lubricating oil is 60,000 cP.

Thus, formulating lubricating oils for both good low temperature pumpability and good high temperature shear viscosity in essence requires the formulator to address mutually exclusive goals; i.e. to maintain low viscosity at very low temperatures (e.g. at engine start-up), while also maintaining sufficiently high viscosity at engine operating temperatures.

The present inventors have discovered that incorporation of a minor amount of an ethylene/α-olefin liquid copolymer in a lubricant composition containing one or more of a Group I to Group V base stock permits formulation of SAE 5W-30 oils with 3.5 cP HTHIS viscosity at KV100 of less than 10.6 cSt. The ethylene/α-olefin liquid copolymers of the present disclosure impart excellent HTHIS viscosity boost, while maintaining very robust low temperature and KV100 viscometrics.

One major component, component A, in the lubricant composition of the present disclosure is a copolymer made from ethylene with one or more alpha-olefins. Consequently, as used herein, the term copolymer encompasses polymers containing 2, 3 or more different monomer moieties. The copolymers in the blend of the disclosure have a number average molecular weight of from 800 to 20,000 and a MWD<5. Importantly, the copolymer contains not more than 50 wt% ethylene. The alpha-olefin moiety of the copolymer will be derived from at least one or more C3, C4 or higher alpha olefins.

Accordingly, suitable alpha-olefinic monomers include those represented by the formula H2C—CHR, wherein R is a straight or branched chain alkyl radical comprising 1 to 18 carbon atoms and preferably 1 to 10 carbon atoms, or alternatively 1 to 3 carbon atoms or alternatively 1 to 2 carbon atoms. When R is a branched chain, the branch is preferred to be at least two carbons away from the double bond.

The copolymers are prepared by copolymerizing a feed containing ethylene and one or more alpha olefins in the weight ratio of 60:40 to 5:95 in the presence of a metalloocene catalyst system. Metalloocene catalyst systems are well known in the art and mention is made of U.S. Pat. Nos. 6.030,930, 5,859,159, incorporated herein by reference, for a description of metalloocene catalysts systems useful for producing the polymers from ethylene and one or more alpha-olefins suitable for the lubricant fluid blends of the present disclosure.

The copolymer is produced by polymerizing a reaction mixture of ethylene and at least one additional alpha-olefin monomer in the presence of a metalloocene catalyst system, preferably in solution. Optionally, hydrogen may be added to regulate the degree of polymerization or molecular weight, and to reduce the amount of unsaturation in the product. In such situations the amount of hydrogen typically will be 0.1 mole % to 50 mole % based on the amount of ethylene.
Any known solvent effective for such polymerization can be used. For example, suitable solvents include hydrocarbon solvent such as aliphatic, cycloaliphatic and aromatic hydrocarbons. The preferred solvents are propane, n-butane, isobutane, pentane, isopentane, hexane, isohexane, heptane, isoheptane, Norpar, Isopar, benzene, toluene, xylene, alkyl aromatic-containing solvents, or mixture of these solvents.

The polymerization reaction may be carried out in a continuous manner, such as in a continuous flow stirred tank reactor where feed is continuously introduced into the reactors and product removed therefrom. Continuously stirred tank reactor (CSTR) method is more preferred because it produces the polymers with narrow molecular weight distribution, lower MWD numbers and better shear stability and better high temperature shear rate viscosity. CSTR is also more advantageous to produce products with more homogeneously randomly distributed alpha-olefin monomers along the polymer backbone. Alternatively, the polymerization may be conducted in a batch reactor, preferably equipped with adequate agitation, to which the catalyst, solvent, and monomers are added to the reaction and left to polymerize wherein for a time sufficient to produce the desired product.

Typical polymerization temperature for producing the copolymers useful herein are in the range of 0°C to 300°C, and preferably 25°C to 250°C, at pressures of 15 to 1500 psig, and preferably 50 to 1000 psig. Typical hydrogen partial pressures are in the range of 0 psi to 300 psi, alternatively 1 psi to 200 psi, alternatively 2 psi to 100 psi, alternatively 15 to 50 psi. Key criteria of choosing H2 pressure is to minimize hydrogenation of feed olefins, to increase catalyst productivity, to reduce degree of unsaturation in the final polymers, to regulate polymer molecular weight at most desirable range while maintaining narrow molecular weight distribution (MWD).

The conditions under which the polymerization is conducted will determine the degree of unsaturation in the resulting copolymer. As is known in the art, the degree of unsaturation of a polymer can be measured by bromine number. In the present disclosure it is preferred that the copolymer have a bromine number below 2 and preferably in the range of 0 to 1. The degree of unsaturation can also be determined by H-NMR method as described in Wo2007011459, Wo2008010856.

In those instances where the product copolymer has a high degree of unsaturation, such as when the copolymer product has a viscosity less than 1000 cSt at 100°C, the copolymer preferably is hydrogenated to provide a final product having a bromine number below 2. The hydrogenation may be carried out in a batch mode or in continuous stirred tank or in a continuous fixed bed operation, using typical hydrogenation catalysts. Examples of the hydrogenation catalysts are nickel on kieselguhr catalyst, Raney Nickel catalyst, many commercial hydrorefining catalysts, such as nickel, cobalt, molybdenum or tungsten on silica, silica-alumina, alumina, zirconium support, etc., or supported Group VIIIIB metals, such as platinum, palladium, ruthenium and rhodium. The hydrogenation conditions may range from room temperature to 300°C, with hydrogen pressure from atmospheric pressure to 2000 psi for long enough residence time to reduce most or all of the unsaturation. The unsaturation degree can be measured by bromine number of iodine index. Preferably the bromine number of the finished product should be below 2. The lower the bromine number the better the oxidative stability. More preferably, the reaction temperature, pressure, residence time, catalyst loading all will be adjusted to achieve 0-1 bromine number.

In instances where the polymerization conditions favor the formation of copolymers having a very low degree of unsaturation, hydrogenation of the copolymer is not necessary and the copolymer can be used directly in forming the lubricant blend.

Particularly beneficial copolymers are those comprising between 10 to 45 wt% ethylene, or even between 15 to 45 wt% ethylene. Likewise, particularly beneficial copolymers according to the present disclosure have been determined to have number average molecular weights between 2000 to 10,000, even between 3000 to 8000, and even between 3000 to 6000, with molecular weight distributions (Mw/Mn) of less than 2.5, or even less than 2.0. A particularly beneficial ethylene/α-olefin copolymer is made from combinations of ethylene and 1-butene in the afore-mentioned combination of monomer weight percentages, molecular weights and MWD. Of particular interest are the polymers made from ethylene and mixed C4 stream, which contains 5 to 95% of 1-butene in the mixed butene stream. This mixed C4 stream is usually readily available from refinery gas stream.

The copolymer is typically in the form of a viscous liquid.

The other major component, component B, in the lubricant composition of the present disclosure is a base oil selected from Group I to Group V base oils and mixtures thereof. Advantageously, the base oil component B is a Group III, Group IV, Group V base oil, GTL base stock or a mixture of the two.

The amounts of ethylene/α-olefin copolymer and base oils in the blends of fluid the present disclosure are not critical and will depend on the intended use of the blend. In general the amount of copolymer will constitute from 1 to 20 wt% of the blend. Generally, it is preferred to be from 2 to 15 wt%, more preferably from 5 to 15 wt%. If a too small amount of the polymer is used, the blend will not have sufficient viscometrics. On the other hand, if too much of the polymer is used, it may be more costly or the blend viscosity may be too high for practical use.

The fluid blends of the present disclosure can be combined with selected lubricant additives to provide lubricant compositions. The additives listed below are typically used in such amounts so as to provide their normal attendant functions. Typical amounts for individual components are also set forth below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Broad Wt %</th>
<th>Preferred Wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity Index Improver</td>
<td>1-12</td>
<td>1-4</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>0.01-3</td>
<td>0.01-1.5</td>
</tr>
<tr>
<td>Oxidation Inhibitor</td>
<td>0.01-5</td>
<td>0.01-1.5</td>
</tr>
<tr>
<td>Dispersant</td>
<td>0.1-10</td>
<td>0.1-5</td>
</tr>
<tr>
<td>Lube Oil Flow Improver</td>
<td>0.01-2</td>
<td>0.01-1.5</td>
</tr>
<tr>
<td>Detergents and Rust Inhibitors</td>
<td>0.001-6</td>
<td>0.01-3</td>
</tr>
<tr>
<td>Pour Point Depressant</td>
<td>0.01-1.5</td>
<td>0.01-1.5</td>
</tr>
<tr>
<td>Antifoaming Agents</td>
<td>0.001-0.1</td>
<td>0.001-0.01</td>
</tr>
<tr>
<td>Antwear Agents</td>
<td>0.001-5</td>
<td>0.001-2</td>
</tr>
<tr>
<td>Extreme Pressure Additives</td>
<td>0.001-5</td>
<td>0.01-0.01</td>
</tr>
<tr>
<td>Seal Swellant</td>
<td>0.1-8</td>
<td>0.1-4</td>
</tr>
<tr>
<td>Friction Modifiers</td>
<td>0.01-3</td>
<td>0.01-1.5</td>
</tr>
<tr>
<td>Fluid Blend of Disclosure</td>
<td>≥80%</td>
<td>≥80%</td>
</tr>
</tbody>
</table>

When other additives are employed, it may be desirable, although not necessary, to prepare additive concentrates comprising concentrated solutions or dispersions of the dispersant, together with one or more of the other additives to form an additive mixture, referred to herein as an additive package whereby several additives can be added simulta-
neously to the base stock to form the lubricating oil composition. Dissolution of the additive concentrate into the lubricating oil may be facilitated by solvents and by mixing accompanied with mild heating, but this is not essential. The concentrate or additive-package will typically be formulated to contain the dispersant additive and optional additional additives in proper amounts to provide the desired concentration in the final formulation when the additive package is combined with a predetermined amount of the fluid blend of the disclosure.

All of the weight percents expressed herein (unless otherwise indicated) are based on active ingredient (A.I) content of the additive, and/or upon the total weight of any additive-package, or formulation which will be the sum of the A.I. weight of each additive plus the weight of total oil or diluent.

The composition of the disclosure may also include a co-base stock to enhance lubricant performance or to improve additive solubility in the base stock. Typically co-base stocks are selected from polar fluids or Group V base stocks useful as lubricants.

Examples of these fluids include many types of esters, alkylaromatics, and oil-soluble polyalkylene glycols. Typical esters used in lubricant formulations include polyol esters, adipate esters, phthalate esters, stearates, etc. Typical alkylaromatics used in lube formulation include alkylated naphthenes, alkylbenzenes, alkyltoluenes, detergent alkylate bottoms, etc. Typical oil-soluble polyalkylene glycols include poly-propylene oxides, polybutylene oxides, etc. Such fluids may be used in amounts of 1 wt% to 60 wt%, although amounts of 1 wt% to 10 wt%, or 1 wt% to 20 wt% are preferred.

The following are examples of the present disclosure and are not to be construed as limiting.

EXAMPLES

Illustrative Example 1

A copolymer was prepared in a continuous mode of operation. In this reaction, polymer grade ethylene, polymer grade 1-butene and polymer grade iso-butene solvent were charged into a 200 gallon reactor after purification through molecular sieve and treatment by injecting 50 ppm tri-butylaluminum. The feed rates for ethylene, 1-butene and iso-butene were 12, 120 and 180 lb/hour, respectively. A catalyst solution, containing 5×10⁻⁵ g/mole/liter of dimethylsilyl-bis (4,5,6,7 tetrahydro-indenyl) zirconium dichloride and methyl-aluminoxane of 1/400 Zr/Al molar ratio in toluene, was charged into the reactor at 13.5 ml/minute. The reactor temperature was maintained at 89.4 °C and 95.6 °C, pressure 237-261 psi and average residence time 2 hours. The crude reaction product was withdrawn from the reactor continuously and washed with 0.4 wt % sodium hydroxide solution followed with a water wash. A viscous liquid product was obtained by devolatilization to remove iso-butane solvent, light stripping at 66 °C/5 psig followed by deep stripping at 140 °C/1 millitorr. The residual viscous liquid was then hydro-processed at 200 °C, 800-1200 psi, H₂ pressure with 2 wt % Ni-on-Kieselgur catalyst for eight hours. The hydrogenated product contained 34 wt % ethylene content and had the following properties: 100 °C. Kᵥ=114.0 cS, 40 °C. Kᵥ=1946.5 cS, VI=145 and pour point = -24 °C. This copolymer had Mn of 2374 and MWD of 1.88.

Illustrative Example 2

This copolymer was prepared in a similar manner as in Example 1, except that the feed rates for ethylene, 1-butene and isobutene were 58, 120 and 283 lb/hour, and the reaction temperature was between 98.3 °C. and 101.4 °C., pressure 290-300 psi and average residence time 1 hour. After hydrofinishing, the residual viscous liquid contained 44 wt % ethylene and had the following properties: 100 °C. Kᵥ=149.9 cS, 40 °C. Kᵥ=2418.4 cS, VI=164 and pour point = -24 °C. This copolymer had Mn of 2660 and MWD of 1.76.

Illustrative Example 3

This copolymer was prepared in a similar manner as in Example 1, except that the feed contained 40 wt % 1-butene, 11 wt % ethylene and 49 wt % isobutane, the reaction temperature was 71 °C., and average residence time was 1 hour. After hydrofinishing, the hydrogenated product contained 19 wt % ethylene and had the following properties: 100 °C. Kᵥ=1894 cS, 40 °C. Kᵥ=42608 cS, VI=278 and pour point = -1 °C. This copolymer had Mn of 5491 and MWD of 2.80.

Illustrative Example 4

This polymer was prepared in a similar manner as in Example 1, except that the feed contained 40 wt % 1-butene, 35 wt % ethylene and 25 wt % isobutane, the reaction temperature was 93.3 °C., and average residence time was approximately 1 hour. After hydrofinishing, the viscous liquid contained 44.5 wt % ethylene and had the following properties: 100 °C. Kᵥ=1495 cS, 40 °C. Kᵥ=49073 cS, VI=230 and pour point = -5 °C. This copolymer had Mn of 5664 and MWD of 2.76.

Formulation Examples

A core passenger vehicle engine oil formulation comprising a mix of Group IV and Group V base oils and fixed additive treat rate was used to compare the viscosity effects of commercially available viscosity index improvers against those of EBC copolymers (EBC-1 and EBC-3) of the present disclosure. Formulation specifics and testing data is set forth in Table 2, below.

### Table 2

<table>
<thead>
<tr>
<th>Wt % Components</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
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<tbody>
<tr>
<td>Base oil</td>
<td>78.55</td>
<td>73.55</td>
<td>68.55</td>
<td>78.55</td>
<td>73.55</td>
<td>68.55</td>
<td>78.55</td>
<td>73.55</td>
</tr>
<tr>
<td>VI Improver</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>SV50</td>
<td>0</td>
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<tr>
<td>LZ Styrene-ester polymer</td>
<td>5</td>
<td>10</td>
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<td>Shellvis 250</td>
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<td>15</td>
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TABLE 2-continued

<table>
<thead>
<tr>
<th></th>
<th>EBC-1*</th>
<th>EBC-3*</th>
<th>Total</th>
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<tbody>
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<td>0</td>
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<td>100</td>
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<tr>
<td></td>
<td>5</td>
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<td>100</td>
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</tbody>
</table>

Testing Results

<table>
<thead>
<tr>
<th>Test</th>
<th>EBC-1</th>
<th>EBC-3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_v @ 100^\circ C$, cS D445-5</td>
<td>10.92</td>
<td>4.1</td>
<td>2.9</td>
</tr>
<tr>
<td>HTHS viscosity, cP D4683</td>
<td>5.17</td>
<td>3.17</td>
<td>3.17</td>
</tr>
<tr>
<td>Avg. MRV @ 40°C D4884-7</td>
<td>13349</td>
<td>43643</td>
<td>27208</td>
</tr>
<tr>
<td>CCS @ -30°C, cP D5293-6</td>
<td>3210</td>
<td>5550</td>
<td>4330</td>
</tr>
</tbody>
</table>

Wt % Components

<table>
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<tr>
<th>Component</th>
<th>EBC-1</th>
<th>EBC-3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additive package</td>
<td>16.45</td>
<td>16.45</td>
<td>16.45</td>
</tr>
<tr>
<td>Base oil</td>
<td>68.55</td>
<td>74.52</td>
<td>60.05</td>
</tr>
<tr>
<td>VI Improver</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test</th>
<th>EBC-1</th>
<th>EBC-3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_v @ 100^\circ C$, cS D445-5</td>
<td>16.28</td>
<td>10.32</td>
<td>8.8</td>
</tr>
<tr>
<td>HTHS viscosity, cP D4683</td>
<td>2.84</td>
<td>3.48</td>
<td>2.9</td>
</tr>
<tr>
<td>Avg. MRV @ 40°C D4884-7</td>
<td>25402</td>
<td>11588</td>
<td>12700</td>
</tr>
<tr>
<td>CCS @ -30°C, cP D5293-6</td>
<td>3550</td>
<td>5230</td>
<td>2710</td>
</tr>
</tbody>
</table>

*The data highlighted in bold is that of the present disclosure.

[0078] FIG. 1 illustrates high temperature high shear rate (HTHS) viscosity versus kinematic viscosity at 100°C for lubricants blended with different high molecular weight polymers. EBC-1 and EBC-3 are shown to provide higher HTHS viscosity than other polymers at any given kinematic viscosity, thus illustrating superior film thickness of the EBC polymers at equal kinematic viscosity. For example, EBC-1 used at 10 wt% in the finished oil formulation allows an SAE 5W-30 oil to deliver film thickness under high shear rate conditions equal to that of SAE 60 grade oils which have a minimum HTHS viscosity requirement of 3.7 cSt minimum according to SAE J300.

[0079] FIG. 2 illustrates MRV low temperature pumpability (at 40°C) versus HTHS viscosity at 150°C for lubricants blended with different high molecular weight polymers. EBC-2 and EBC-3 are shown to provide lower MRV viscosities at any given HTHS viscosity, thus illustrating superior low temperature pumpability characteristics of the EBC polymers.

[0080] The data in Table 2 above indicate the ability to formulate lubricating oil compositions which have HTHS viscosities (≥3.5 cP) typically specified by many European engine builders, while robustly meeting $K_v_{100}$ limits for 30 weight oils, and while concurrently having MRV at -40°C at levels well below the upper limit for 0W oils.

[0081] Applicants have attempted to disclose all embodiments and applications of the disclosed subject matter that could be reasonably foreseen. However, there may be unforeseeable, insubstantial modifications that remain as equivalents. While the present invention has been described in conjunction with specific, exemplary embodiments thereof, it is evident that many alterations, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description without departing from the spirit or scope of the present disclosure. Accordingly, the present disclosure is intended to embrace all such alterations, modifications, and variations of the above detailed description.

[0082] All patents, test procedures, and other documents cited herein, including priority documents, are fully incorporated by reference to the extent such disclosure is not inconsistent with this invention and for all jurisdictions in which such incorporation is permitted.

[0083] When numerical lower limits and numerical upper limits are listed herein, ranges from any lower limit to any upper limit are contemplated.

What is claimed is:

1. A lubricant composition comprising a blend of Group I to Group V base stocks, or mixtures thereof, and an ethylene/α-olefin copolymer made from ethylene with one or more α-olefin, wherein the α-olefin has from 3 to 18 carbon atoms and the ethylene/α-olefin copolymer has a number average molecular weight between 800 and 20,000 and a molecular weight distribution of less than 3.0.

2. The lubricant composition of claim 1, wherein the ethylene/α-olefin copolymer comprises between 10 wt% and 45 wt% ethylene content.

3. The lubricant composition of claim 1, comprising between 1 wt% to 20 wt% of the ethylene/α-olefin copolymer.

4. The lubricant composition of claim 3, comprising between 2 to 15% of the ethylene/α-olefin copolymer.
5. The lubricant composition of claim 1, wherein the ethylene/α-olefin copolymer has a number average molecular weight ranging from 2000 to 10,000.

6. The lubricant composition of claim 5, wherein the ethylene/α-olefin copolymer has a number average molecular weight ranging from 3000 to 6000.

7. The lubricant composition of claim 6, wherein the ethylene/α-olefin copolymer has a number average molecular weight ranging from 3000 to 6000.

8. The lubricant composition of claim 1, wherein the ethylene/α-olefin copolymer is made with metalloocene catalysts.

9. The lubricant composition of claim 1, wherein the base stock is a Group IV base stock.

10. The lubricant composition of claim 1, wherein the base stock is a Group V base stock.

11. The lubricant composition of claim 1, wherein the base stock is a mixture of a Group IV base stock and a Group V base stock.

12. The lubricant composition of claim 1, wherein the ethylene/α-olefin copolymer is a liquid ethylene/1-butene copolymer.

13. The lubricant composition of claim 3, wherein the ethylene/α-olefin copolymer is a liquid ethylene/1-butene copolymer.

14. The lubricant composition of claim 1, wherein the ethylene/α-olefin copolymer has a molecular weight distribution of less than 2.5.

15. The lubricant composition of claim 14, wherein the ethylene/α-olefin copolymer has a molecular weight distribution of less than 2.0.

16. The lubricant composition of claim 1, wherein the composition has a high temperature shear viscosity (HTTHS) according to ASTM D4683 of greater than 2.5858×10^5pLn(100°C. Kυ, in cS)=2.6738.

17. The lubricant composition of claim 1, wherein the composition has a high temperature shear viscosity (HTTHS) according to ASTM D4683 of at least 3.5 cP and a mini rotary viscosity (MRV) at -40°C according to ASTM D4684 of less than 15,000 cP.

18. The lubricant composition of claim 1, wherein the composition has a MRV viscosity at -40°C C, according to ASTM D4684 of less than 1.838.8×10^0.5923×(HTTHS vs in cP) cP.

19. The lubricant composition of claim 1, wherein the composition has a high temperature shear viscosity (HTTHS) according to ASTM D4683 of at least 2.9 cP and a mini rotary viscosity (MRV) at -40°C according to ASTM D4684 of less than 1.838.8×10^0.5923×(HTTHS vs in cP).

20. The lubricant composition of claim 1, wherein the composition has a high temperature shear viscosity (HTTHS) according to ASTM D4683 of at least 2.9 cP and a mini rotary viscosity (MRV) at -40°C according to ASTM D4684 of less than 26,000 cP.

21. The lubricant composition of claim 1, wherein the composition has an HTTHS of at least 2.6 cP and a kinematic viscosity at 100°C of less than 16 cSt.

22. The lubricant composition of claim 1, wherein the ethylene/α-olefin copolymer is a liquid ethylene/1-butene copolymer.

23. The lubricant composition of claim 22, wherein the ethylene/1-butene copolymer comprises between 19 wt % and 45 wt % ethylene content.

24. The lubricant composition of claim 23, wherein the ethylene/1-butene copolymer has a number average molecular weight between 2000 and 6,000 and a molecular weight distribution of less than 2.5.

25. The lubricant composition of claim 1, further comprising lubricant additives selected from viscosity index improvers, corrosion inhibitors, dispersants, oxidation inhibitors, detergents, rust inhibitors, antiwear agents, anti-foaming agents, flow improvers, friction modifiers, seal swellants, and combinations thereof.

26. The lubricant composition of claim 12 including less than 30 wt % of the ethylene-1-butene copolymer.

27. The lubricant composition of claim 26 including between 1 wt % and 20 wt % of the ethylene-1-butene copolymer.

* * * * *