LUBRICANT COMPOSITION CONTAINING ETHYLENE-ALPHA OLEFIN COPOLYMER VISCOSITY MODIFIER

FIG. 1

LZ 569 Ester
C200
EBC/ET001
EBC/ET003
SV20
SV50

HTHS Visc-cs

5
5.5
6

100°C Kv, cS

3
3.5
4

y = 2.5858ln(x) - 2.6738

(51) International Patent Classification:
CIOM 169/04 (2006.01)

(21) International Application Number: PCT/US20 10/000946

(22) International Filing Date: 30 March 2010 (30.03.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/384,402 3 April 2009 (03.04.2009) US

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Published:
— with international search (Art. 21(3))

(54) Title: LUBRICANT COMPOSITION CONTAINING ETHERYLENE-ALPHA OLEFIN COPOLYMER VISCOSITY MODIFIER

(57) Abstract: Provided are lubricant compositions containing ethylene/α-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/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.
LUBRICANT COMPOSITION CONTAINING ETHYLENE-ALPHA

OLEFIN COPOLYMER VISCOSITY MODIFIER

FIELD

[0001] This disclosure relates to lubricant compositions containing ethylene/\(\alpha\)-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 D4684, 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\(^{\circ}\)C), Method of Testing for Kinematic Viscosity of Transparent and Opaque Liquids, and 2. ASTM D4683 (at 150\(^{\circ}\)C), Standard Test Method for Measuring Viscosity at High Shear Rate and High Temperature by Tapered Bearing Simulator. Table 1 below outlines the
high and low temperature requirements for the recognized SAE grades for engine oils.

TABLE 1

<table>
<thead>
<tr>
<th>SAE Viscosity Grade</th>
<th>Low-Temperature (°C) Cranking Viscosity[3], mPa·s Max</th>
<th>Low-Temperature (°C) Pumping Viscosity[4] (mPa·s) Max with No Yield Stress</th>
<th>Low-Shear-Rate Kinematic Viscosity[5] (mm²/s) at 100 °C Min</th>
<th>Low-Shear-Rate Kinematic Viscosity[5] (mm²/s) at 100 °C Max</th>
<th>High-Shear-Rate Viscosity[6] (mPa·s) at 150 °C Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>0W</td>
<td>60,000 at -35</td>
<td>60,000 at -40</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5W</td>
<td>60,000 at -30</td>
<td>60,000 at -35</td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10W</td>
<td>70,000 at -25</td>
<td>60,000 at -30</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15W</td>
<td>70,000 at -20</td>
<td>60,000 at -25</td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20W</td>
<td>90,000 at -15</td>
<td>60,000 at -20</td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25W</td>
<td>13,000 at -10</td>
<td>60,000 at -15</td>
<td>9.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>5.6</td>
<td>&lt;9.3</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>9.3</td>
<td>&lt;12.5</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>12.5</td>
<td>&lt;16.3</td>
<td>2.9 (5W-40, 5W-40, and 10W-40 grades)</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td>3.7 (10W-40, 20W-40, 25W-40) grades)</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>12.5</td>
<td>&lt;16.3</td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>16.3</td>
<td>&lt;21.9</td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.9</td>
<td>&lt;26.1</td>
<td></td>
<td>3.7</td>
</tr>
</tbody>
</table>

1 Notes: 1 mPa·s = 1 cp 1 mm²/s = 1 cSt
2 All values are critical specifications as defined by ASTM D344 (Section 3) with 95% confidence that ATV meets/exceeds specification (Fig 2)
3 ASTM D 5293 - Automated measurement with reproducibility R² > 7% 3% mean
4 ASTM D 4684 - Note that the presence of any yield stress detectable by this method constitutes a failure regardless of viscosity
5 ASTM D 445
6 ASTM D 4683 or CEC L 36 A 90 (ASTM D4741) If method ASTM D 5481 is used to determine High Shear Rate Viscosity the 95% high confidence limits must be recalculated using Reproducibility = 5-4% of the mean

[0004] In addition to the viscosity temperature relationship, other properties are, of course, required for an engine oil including resistance to oxidation under the high temperatures encountered in the engine, resistance to hydrolysis in the presence of the water produced as a combustion product (which may enter the lubricating circulation system as a result of ring blow-by) and since the finished oil is a combination of base stock together with additives, these properties should be achieved in the final, finished lubricant so that it possesses the desired balance of properties over its useful life.

[0005] In recent years, considerable attention has been given to the tribological behavior of lubricants under conditions of high shear rate and high pressure. At high shear rates, as in a lubrication contact zone, considerable shear
thinning may occur, which results in a decrease in the thickness of the lubricant film separating the relatively moving surfaces with the possibility that inadequate film thickness may be maintained under these conditions. As a counter to this tendency, it would be desirable to provide lubricant compositions which can function effectively under high temperature conditions and which possess good rheological properties to provide adequate film thickness and wear protection by resisting shear thinning under conditions of high temperature and high shear rate as well as high contact pressure, and good low temperature pumpability to ensure adequate lubrication on low temperature engine startup.

[0006] The gasoline and diesel engine manufacturers in North America, Europe and Asia Pacific demand lubricants of increasingly higher quality and higher performance. Both the North American and European automobile manufacturers associations are regularly introducing new performance categories that simultaneously reflect and stimulate improvements in lubricant quality and performance. Key performance areas are fuel economy, longer drain intervals with extended performance retention, better soot handling, lower emissions, and improved low-temperature performance. Several of these performance features push the industry to use basestocks with lower viscosity, better oxidation stability, lower volatility, higher saturates, lower sulphur, lower nitrogen, and lower aromatics.

[0007] In particular, reduced vehicle emissions are partially achieved by improved fuel economy and better low-temperature starting capability (C. J. May, J. J. Habeeb, A. M. White, Lubrication Engineering, 43 (7), 557-567), both of which lower fuel consumption and consequently reduce gaseous emissions. Low-viscosity SAE OW-XX (where XX=40 or lower) grade lubricants can demonstrate both of these performance characteristics. Relative improvements in fuel economy can be achieved by low-viscosity lubricants compared to a typical high-viscosity lubricant such as SAE 20W-50 (fuel economy improvement equal to 0.44% versus SAE 40 grade reference lubricant). For example, an SAE 0W-30
viscosity grade can achieve over 2.51% fuel economy improvement versus the same reference lubricant.

[0008] Many European engine builders typically recommend oils which have a minimum high temperature shear viscosity (HTHS) 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.

[0009] 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 (Kvioo) 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 Kvioo of 12 cSt or higher, while the Kvioo specification for SAE 30 ranges from 9.3 cSt minimum to 12.5 cSt maximum.

[00010] 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 basestocks 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.

[00011] 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 basestocks 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 viscometrics 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.

[00012] U.S. Patent 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 OW or better.

[00013] U.S. Patent 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
metallocene catalyst to provide a polymer which is then isomerized and hydrogenated to produce the liquid polymer.

(00014) U.S. Published Patent Application No. 2003/0236177 Al, 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 hydroprocessed oil having a VI greater than 80.

SUMMARY

[00015] 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.

[00016] In another embodiment, the copolymer of the lubricant composition can comprise between 10 wt% and 45 wt% ethylene content.

[00017] In another embodiment, the lubricant composition can comprise between 1 wt% to 20 wt% of the ethylene/α-olefin copolymer.

[00018] In another embodiment, the lubricant composition can comprise between 2 to 15% of the ethylene/α-olefin copolymer.

[00019] In another embodiment, the copolymer of the lubricant composition has a number average molecular weight ranging from 2000 to 10,000.
In another embodiment, the copolymer of the lubricant composition has a number average molecular weight ranging from 3000 to 8000.

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

Conveniently, the copolymer is made with metallocene catalysts.

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

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

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

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

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.

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 (HTHS) according to ASTM D4683 of higher than $2.5858 \times \ln(100^0C \text{ Kv, in } \text{cS}) - 2.6738$.

In another embodiment, the lubricant composition has a high temperature shear viscosity (HTHS) 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 $1.838.8 \times e^{(\alpha_{5923} \times \text{HTHS in cP})}$.

In another embodiment, the lubricant composition has a high temperature shear viscosity (HTHS) 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 $1.838.8 \times e^{(\alpha_{5923} \times \text{HTHS in cP})}$.

In another embodiment, the lubricant composition has a high temperature shear viscosity (HTHS) 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 HTHS 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**

[00039] Figure 1 is a graph of HTHS viscosity vs. 100°C Kv for formulated lubricants.

[00040] Figure 2 is a graph of MRV at -40°C vs. HTHS Viscosity for formulated lubricants.

**DETAILED DESCRIPTION**

[00041] 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.

[00042] European engine builders recommend oils which have a minimum high temperature shear viscosity (HTHS) 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.

[00043] 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.
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 HTHS viscosity at KV100 of less than 10.6 cSt. The ethylene/α-olefin liquid copolymers of the present disclosure impart excellent HTHS 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<3. 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=CHR₁ wherein R₁ 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 Ri is a branched chain, the branch is preferred to be at least two carbons away from the double bond.

[00049] 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 metallocene catalyst system. Metallocene catalyst systems are well known in the art and mention is made of U.S. Pat. No. 6,030,930, 5,859,159, incorporated herein by reference, for a description of metallocene 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.

[00050] The copolymer is produced by polymerizing a reaction mixture of ethylene and at least one additional alpha-olefin monomer in the presence of a metallocene 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.

[00051] 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, alkylaromatic-containing solvents, or mixture of these solvents.

[00052] 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 high shear rate viscosity. CSTR is also more advantageous to produce products with more
homogenously 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 therein for a time
sufficient to produce the desired product.

[00053] 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).

[00054] 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 more preferably in the range of 0 to 1. The degree
of unsaturation can also be determined by H-NMR method as described in
WO200701459, WO2008010856.

[00055] 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 stir 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 hydrotreating 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.

[00056] 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.

[00057] Particularly beneficial copolymers are those comprising between 10 to 45 wt% ethylene, or even between 19 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>Additive</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>0.01-6</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>0.01-0.1</td>
<td>0.001-0.01</td>
</tr>
<tr>
<td>Antiwear Agents</td>
<td>0.001-5</td>
<td>0.001-2</td>
</tr>
<tr>
<td>Extreme Pressure Additives</td>
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<td>0.001-2</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>&gt;80%</td>
<td>&gt;80%</td>
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</tbody>
</table>
[00062] 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 simultaneously 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.

[00063] 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.

[00064] 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.

[00065] 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, sibacate esters, phthalate esters, sterates, etc. Typical alkylaromatics used in lube formulation include alkylated naphthalenes, alkylbenzenes, alkyltoluenes, detergent alkylate bottoms, etc. Typical oil-soluble polyalkylene glycols include poly-propylene oxides, poly-butylene 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.

[00066] The following are examples of the present disclosure and are not to be construed as limiting.

EXAMPLES

Illustrative Example 1:

[00067] A copolymer was prepared in a continuous mode of operation. In this reaction, polymer grade ethylene, polymer grade 1-butene and polymer grade iso-butane solvent were charged into a 200 gallon reactor after purification through molecular sieve and treatment by injecting 50 ppm tri-t-butylaluminum. The feed rates for ethylene, 1-butene and iso-butane were 12, 120 and 180 lb/hour, respectively. A catalyst solution, containing 5x10^-6 g-mole/liter of dimethylsilylbis (4,5,6,7 tetrahydro-indenyl) zirconium dichloride and methylaluminoxane of 1/400 Zr/Al molar ratio in toluene, was charged into the reactor at 13.5 ml/minute. The reactor temperature was maintained 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 devolitalization 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-finished at 200°C, 800-1200 psi H₂ pressure with 2 wt% Ni-on-Kieselguhr catalyst for eight hours. The hydrogenated product contained 34 wt% ethylene content and had the following properties: 100°C Kv=I 14.0 cS, 40°C Kv-1 946.5 cS, VI=145 and pour point = -24°C. This copolymer had Mn of 2374 and MWD of 1.88.
Illustrative Example 2:

[00068] This copolymer was prepared in a similar manner as in Example 1, except that the feed rates for ethylene, 1-butene and isobutane were 58, 120 and 283 lb/hour, and the reaction temperature was between 98.3°C and 101.1°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: $100^0\text{C} \text{Kv}=149.9$ cS, $40^0\text{C} \text{Kv}=2418.4$ cS, VI=164 and pour point = -24°C. This copolymer had Mn of 2660 and MWD of 1.76.

Illustrative Example 3:

[00069] 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: $100^0\text{C} \text{Kv}=1894$ cS, $40^0\text{C} \text{Kv}=42608$ cS, VI=278 and pour point = -1°C. This copolymer had Mn of 5491 and MWD of 2.80.

Illustrative Example 4:

[00070] 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: $100^0\text{C} \text{Kv}=1493$ cS, $40^0\text{C} \text{Kv}=49073$ cS, VI=230 and pour point = 5°C. This copolymer had Mn of 5664 and MWD of 2.76.
Formulation Examples:

[00071] 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-I and EBC-3) of the present disclosure. Formulation specifics and testing data is set forth in Table 2, below.
Table 2

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<th>D</th>
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</table>

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

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.

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 KVioo limits for 30 weight oils, and while concurrently having MRV @ -40°C at levels well below the upper limit for OW oils.

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.
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.

When numerical lower limits and numerical upper limits are listed herein, ranges from any lower limit to any upper limit are contemplated.
CLAIMS:

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 8000.

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 metallocene 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/\(\alpha\)-olefin copolymer is a liquid ethylene/1-butene copolymer.

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

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

15. The lubricant composition of claim 14, wherein the ethylene/\(\alpha\)-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 (HTHS) according to ASTM D4683 of greater than 2.5858 x Ln(IOO°C Kv, in cS) - 2.6738.

17. The lubricant composition of claim 1, wherein the composition has a high temperature shear viscosity (HTHS) 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 according to ASTM D4684 of less than $1.838.8 \times e^{(\alpha_{5923} x)}$ (HTHS vis in cP).

19. The lubricant composition of claim 1, wherein the composition has a high temperature shear viscosity (HTHS) 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 $1.838.8 \times e^{(\alpha_{5923} x)}$ (HTHS vis incP).

20. The lubricant composition of claim 1, wherein the composition has a high temperature shear viscosity (HTHS) 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 HTHS of at least 2.6 cP and a kinematic viscosity at 100°C of less than 16 cSt.

22. The lubricant composition of claim 21, 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.
FIG. 1

$y = 2.5858 \ln(x) - 2.6738$
FIG. 2

\[ y = 1838.8e^{0.5923x} \]

- LZ-Sty-Ester
- SV200
- EBC(E7001)
- EBC(E7003)
- SV50
- Expon. (limit)

MRV at 40°C, cP vs. HTHS Vis, cP
INTERNATIONAL SEARCH REPORT

International application No
PCT Λ J S 10/00946

A CLASSIFICATION OF SUBJECT MATTER
IPC(8) - C10M 169/04 (2010.01)
USPC - 525/320, 322, 526/348, 585/10
According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
USPC 525/320, 322, 526/348, 585/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC 525/920, 322, 526/348, 585/10 and all USPC classes (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (USPT, PGIP, EPAB, JPAB), Google, Google Scholar
Search Terms Ethylene, copolymer, lubricating oil, lubricant, molecular weight distribution, MW, D4683, D4684, Group V, base stock, olefin, ASTM, high temperature shear, HTHS, butene, rotary viscosity, NAMW, kinematic viscosity

C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
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<th>Relevant to claim No</th>
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<td>US 2003/0236177 A1 (wu et al) 25 December 2003 (25 12 2003), para [0012]-[0014], [0023], [0026], [0030], [0034], [0035], Table II</td>
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<td>US 2006/0199743 A1 (ROSENBAUM et al) 07 September 2006 (07 09 2006), Table VIII</td>
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D Further documents are listed in the continuation of Box C

* Special categories of cited documents
"A" Document defining the general state of the art which is not considered to be of particular relevance
"E" Earlier application or patent but published on or after the international filing date
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"&" Document member of the same patent family

Date of the actual completion of the international search
13 May 2010 (13 05 2010)

Date of mailing of the international search report
21 MAY 2010

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