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(54) **OIL-IN-OIL EMULSION LUBRICANTS FOR ENHANCED LUBRICATION**

ÖL-IN-ÖL-EMULSIONSSCHMIERMITTEL FÜR VERBESSERTE SCHMIERUNG

LUBRIFIANTS EN EMULSION HUILE DANS L'HUILE PERMETTANT UNE LUBRIFICATION RENFORCEE

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Description

FIELD OF THE INVENTION

[0001] The present invention is related to novel lubricants characterized as stable liquid emulsions or liquid-in-liquid dispersions and methods of lubrication using the same. In particular, the invention is related to lubricant emulsions that are comprised of a low viscosity carrier fluid and a relatively small amount of a higher viscosity fluid, the combination imparting superior lubrication properties to the composition such as low viscosity and thick lubricating films.

BACKGROUND OF THE INVENTION

[0002] Lubrication results from the formation of a film of lubricant that is entrained into movable contacting surfaces of a mechanical assembly. The film separates the surfaces, thereby reducing friction and mechanical wear. Thicker films generally impart greater surface protection. Certain properties of lubricants are associated with lubrication performance and film thickness. In the case of liquid lubricants, viscosity of the fluid is directly correlated with the magnitude of the film (or film thickness) that builds and separates moving surfaces under contact, the greater viscosities contributing to greater film thickness.

[0003] A common lubrication condition involves elastically deformed surfaces in concentrated contact called elastohydrodynamic lubrication (EHL). According to EHL, the variation of viscosity with pressure (expressed as the pressure-viscosity coefficient) contributes to lubricant film thickness. For instance, liquid lubricants of identical viscosity at an arbitrary operating temperature may differ in film thickness. The lubricant with a higher pressure-viscosity coefficient provides greater film thickness. However, lubricants with high pressure-viscosity coefficients typically show greater variation of viscosity with temperature. The variation of viscosity with temperature is generally expressed as viscosity index (VI), and lubricants showing greater variation (reduced film thickness at higher temperatures) are characterized as having lower VI. Thus, the lower VI counterbalances any benefit derived from a high pressure-viscosity coefficient at higher temperatures. Only few liquids, such as those disclosed in U.S. Pat. No. 4,762,635, have pressure-viscosity coefficients able to compensate for a lower VI at typical operating temperatures.

[0004] Unfortunately, many lubricants that produce desirably thick films also have relatively high viscosities. High viscosity lubricants often contribute to problems such as poor flow properties, increased operating temperatures, and decreased operating efficiency of the lubricated device. Thus, lubricants with lower viscosities and thicker films are currently being developed for their desirable properties. For instance, U.S. Pat. No. 4,549,774 describes lithium salt-containing polyether and polyglycol fluids that show enhanced EHL film thickness (with respect to both temperature and pressure) and no corresponding increase in fluid kinematic viscosity.

[0005] Other lubricating difficulties involve the need for multiple lubricating properties for a single lubricated device. For instance, mechanical assemblies operating at a range of temperatures or having components that require different lubricating conditions have need for versatile lubricants that provide surface protection under a wide range of conditions. WO00/29522 provides polyether lubricants that are miscible with the relatively non-polar synthetic hydrocarbons such as PAO. Multi-phase lubricants have been developed which employ a unique phase change to meet a variety of lubricating requirements. For instance, U.S. Pat. Nos. 5,602,085; 5,599,100; 5,485,895; and 5,465,810 reveal multi-phase lubricants having partially to substantially miscible components suitable for use in complex systems requiring a single lubricant. The lubricants disclosed therein depend on the formation of a single phase mixture of the components at elevated temperature or pressure such that lubricating properties unique from those of the separate components can be achieved.

[0006] As is evident, versatile lubricants that allow both maximum protection of contacting surfaces and maximum operating efficiency are desirable for a wide range of lubrication applications. In particular, liquid lubricants that have increased film thickness yet retain desirably low viscosities would promote greater operating efficiency and cost effectiveness of lubricated mechanical devices operating under elastohydrodynamic lubricating conditions. The present invention disclosed herein is directed toward improved lubricants which show such desirable properties as low viscosity and thick lubricating films.

SUMMARY OF THE INVENTION

[0007] The present invention encompasses novel lubricant compositions comprising at least two components, a carrier fluid and a minor amount of higher viscosity fluid, which are substantially immiscible. Together the two fluids form a stable emulsion capable of producing a lubricating film thickness greater than the expected film thickness.

[0008] Specifically, lubricant compositions of the present invention comprise a low viscosity, carrier fluid and a minor amount of an immiscible or semi-miscible higher viscosity fluid. Lubricant compositions of the present invention comprise a relatively non-polar, hydrocarbon carrier fluid and a minor amount of an immiscible or semi-miscible polar, hydrocarbon fluid. Lubricant compositions of the present invention comprise a hydrocarbon carrier fluid and from 0.01% to 10% by
weight of a higher viscosity poly-THF ester fluid.

[0009] The carrier fluid comprises 10 to 90% by weight PAOs and 10 to 90% by weight alkylated aromatics such as an alkylated naphthalene fluid.

[0010] In further aspects of the present invention, a method of lubrication is contemplated which includes applying a lubricant to a mechanical assembly having movable contacting surfaces wherein the lubricant comprises a stable emulsion of (1) the carrier fluid and (2) the higher viscosity fluid which together produce a film thickness greater than the expected film thickness.

[0011] In further aspects of the present invention, a method of lubrication is encompassed which includes the steps of providing a lubricant comprising a) hydrocarbon carrier fluid and b) poly-THF ester, and applying the lubricant to a mechanical assembly having movable contacting surfaces operating under elasto-hydrodynamic lubricating conditions. The carrier fluid contains 10 to 90% by weight PAOs and 10 to 90% by weight alkylated aromatics preferably alkylated naphthalenes. The poly-THF ester fluid is present in the lubricant in an amount of from about 0.01 % to about 10% by weight.

[0012] In yet another aspect of the present invention, lubricant compositions are encompassed that are prepared by a method comprising the steps of:

(a) combining the carrier fluid and the higher viscosity fluid to form a mixture, wherein the fluids are substantially immiscible;
(b) heating the mixture with agitation to a temperature at which the fluids dissolve to form a solution; and
(c) cooling the solution to a temperature at which the fluids separate into a continuous phase and a discontinuous phase to yield an emulsion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Figure 1 displays comparative data for compositions of the present invention showing enhanced film thickness, expressed as LP, as a function of temperature.

[0014] Figure 2 displays comparative data for compositions of the present invention showing enhanced film thickness, expressed as LP, as a function of viscosity.

[0015] Figure 3 displays reduced shear strength for compositions of the present invention with respect to shear strength of the carrier alone.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0016] The term "higher viscosity fluid" and "high viscosity fluid" are used interchangeably herein and refer to fluids that have a viscosity higher than the viscosity of the carrier fluid.

[0017] The terms "lubricating film thickness," "EHL film thickness," and "film thickness" are used interchangeably herein and are meant to refer to the actual magnitude of the layer of lubricant residing on a lubricated surface in a mechanical assembly operating under the lubricating conditions.

[0018] The term "expected film thickness," as used herein, refers to a theoretical or calculated film thickness based on the expected contribution of the two fluid components. For example, the expected film thickness may be calculated from the dynamic viscosity of the mixture. In view of the minor amount of the higher viscosity fluid in the mixture the expected film thickness may also be calculated from the dynamic viscosity or the dynamic viscosity and pressure-viscosity coefficient of the carrier fluid alone. Thus, the expected film thickness represents a film thickness based on the viscosity of at least the carrier fluid.

[0019] Furthermore, the term "substantially immiscible," refers to fluids that tend to remain as separate phases when in contact with each other and do not readily form a single phase solution, even under mixing conditions such as elevated temperature and agitation.

[0020] As used herein, the term "stable emulsion" denotes a liquid composition having a continuous hydrocarbon, liquid phase and a discontinuous, hydrocarbon, liquid phase with the discontinuous phase remaining substantially evenly dispersed throughout the continuous phase for an extended time period, including reasonable storage and usage times.

[0021] Preferred embodiments of the present invention can be characterized as novel liquid lubricants having at least two distinct liquid phases combined together as a stable emulsion. The components of the lubricant emulsion include a continuous phase of carrier fluid and a discontinuous phase of a fluid having a viscosity higher than the carrier fluid. These novel lubricants may be useful in many applications and are desirable for their superior properties related to low viscosities, improved film thickness, and better lubricating performance.

[0022] Carrier fluids comprising blends of polyalphaolefins and alkylated aromatics are used for the present invention.
The polyalphaolefins may be derived from alphaolefins which include, but are not limited to, from C₂ to about C₃₂ alphaolefins. A preferred PAO is PAO6 which is characterized as a polyalphaolefin fluid having a kinematic viscosity of about 6 × 10⁻⁶ m²/s (cSt) at 100°C. Polyalphaolefins are well known to those skilled in the art and are well described in the literature, such as, for example, U.S. Pat. No. 4,041,098. A preferred alkylated aromatic may be alkylated naphthalene (AN). PAO-based carrier fluids, containing preferably from 50% to 90% by weight PAO and from 10% to 50% by weight alkylated aromatic, or even more preferably 75% to 85% by weight PAO and 15% to 25% by weight alkylated aromatic, are encompassed by the present invention. Other suitable PAO/alkylated aromatic blends include those disclosed in U.S. Patent No. 5,602,086.

The lubricants of the present invention also contain proportionally smaller amounts of a high viscosity fluid which contribute to lubrication performance. The high viscosity fluid may be characterized as having greater viscosity than the carrier fluid. Viscosities range from 10 to 10,000 × 10⁻⁶ m²/s (cSt) at 100°C. The high viscosity fluid is also preferably substantially immiscible with the carrier fluid over the range of temperatures likely to be encountered under storage and lubricating conditions so as to maintain a two-phase system throughout its use.

Poly-tetrahydrofuran (p-THF) ester fluids can be made by the condensation reaction between p-THF and dibasic carboxylic acids to yield crosslinked p-THF products which are further reacted with monobasic carboxylic acids to endcap the terminal hydroxyl groups in a second condensation reaction. The resulting p-THF ester fluid may be described as a mixture of polymers comprising one or more each of the structural polymeric components depicted in formulas Ia, Ib, and Ic below. Formula Ia displays the repeating THF unit and Formula Ib displays the end-capped p-THF units of the ester fluid wherein R1 is hydrogen or any substituted or unsubstituted C₁ to C₃₀ alkyl, aryl, or aralkyl group, including but not limited to methyl, ethyl, n-propyl, isopropyl, n-butyl, t-butyl, phenyl, and benzyl. In addition, formula Ic depicts the p-THF linking dicarboxylic acid repeating units of the ester fluid wherein R² and R³ are, independently, hydrogen or any substituted or unsubstituted C₁ to C₃₀ alkyl, aryl, alkoxy, aryloxy, or aralkyl group. Variables m and p can be, independently, any integer of 1 or more. Other repeating units derived from, such as for example, substituted or unsubstituted ethylene glycols, propylene glycols, and cyclic ethers, may also be incorporated into the p-THF ester fluids. Further, the p-THF ester fluids may be characterized as having viscosities ranging from about 150 to about 10,000 × 10⁻⁶ m²/s (cSt) at 100°C.

In preferred embodiments of the present invention, the higher viscosity fluid is dispersed in the carrier fluid.
such that a stable emulsion or liquid-in-liquid dispersion is formed. The carrier fluid constitutes the continuous phase while the higher viscosity fluid constitutes the discontinuous phase of the stable emulsion. The higher viscosity fluid preferably remains evenly dispersed throughout the carrier for relatively long periods of time such that the emulsion is stable for its duration of use and reasonable storage time. Preferred lubricants of the present invention are characterized by small droplets of the high viscosity fluid dispersed in the carrier fluid. Ideally, the droplets are of a size sufficient to prevent rapid coalescence, thus contributing to emulsion stability. The mean number average droplet size (as determined for example by laser light scattering experiments) may range from about 0.01 microns to about 10 microns, or more preferably from about 0.1 microns to about 5 microns, or even more preferably, may be about 1 micron.

The higher viscosity fluid is preferably present in the lubricant in an amount sufficient to promote improved lubrication performance relative to the carrier fluid. In addition, a sufficient amount of higher viscosity fluid is desirable to promote the formation of a two-phase lubricant. As such, an amount of fluid may be required such that it surpasses the critical miscibility concentration. Generally, the higher viscosity fluid will be present in the carrier fluid in relatively small amounts. Typically, the amount of higher viscosity fluid in the lubricant ranges from preferably from about 0.1% to about 10% by weight, or even more preferably from about 0.1% to about 3% by weight. The presently described lubricant emulsions comprise ester fluids in amounts ranging from 0.01% to 10% by weight, or more preferably from about 0.01% to about 3% by weight, or even more preferably from about 0.01% to about 1.6% by weight.

In some embodiments, the lubricant comprises 98.4% 4:1 PAO6/AN mixture by weight and 1.6% by weight p-ThF ester fluid.

The lubricants of the present invention may also contain additives that impart certain desirable properties to the compositions. The additives contemplated for use herein can be, for example, emulsifiers, rust and corrosion inhibitors, metal passivators, dispersants, antioxidants, thermal stabilizers, or EP/antiwear agents. These additives materials do not detract from the value of the compositions of this invention, rather they serve to impart their customary properties to the particular compositions in which they are incorporated.

In general, the lubricant emulsions of the present invention can be prepared by any method known in the art for making stable emulsions. More specifically, the lubricants described herein can be prepared by heating the carrier and the high viscosity fluid together to a temperature where they dissolve with agitation followed by cooling the mixture. A protocol for producing lubricants of the present invention may include the steps of combining carrier fluid and higher viscosity fluid, heating the resulting mixture with simultaneous agitation to a temperature at which the fluids substantially dissolve, and cooling the dissolved fluids to a temperature at which the fluids separate into a continuous phase and a discontinuous phase so that an emulsion is formed.

Some of the most important and intriguing aspects of the presently described lubricants include their unexpectedly superior lubricating performance. Generally, better lubricants form thicker films on the surfaces they coat. However, greater film thickness is a characteristic of fluids having high viscosity, itself an undesirable property that contributes to lower operating efficiencies. The lubricants described herein counter this film thickness-viscosity trend by showing unusually greater film thickness for their measured viscosities. This unusual property has been observed in a point contact optical EHL film thickness measurement device in which EHL film thickness is measured as a function of temperature and dynamic viscosity (product of kinematic viscosity and density). EHL film thickness can be expressed as LP, the lubricant parameter, which is a product of the dynamic viscosity, \( \eta_0 \) (10^{-3} Pa.s (cP)), and the pressure-viscosity coefficient, \( \alpha \) (6.9 Pa^{-1} (psi^{-1})), according to equation 1:

\[
LP = 10^{11} \eta_0 \alpha \quad \text{(Eq. 1)}
\]

As apparent from equation 1, film thickness is expected to increase upon increasing the values for dynamic viscosity or pressure-viscosity coefficient, both values which are readily determined by one skilled in the art. LP is the lubricant contribution to film thickness in EHL contacts. The lubricant parameter (LP) concept is fully described in the industry publication Mobil EHL Guidebook, Fourth edition, Mobil Oil Corp., Technical Publications, Fairfax, VA, 1992.

Since the lubricants of the present invention show only a slight increase in viscosity relative to carrier fluid alone, essentially no detectable difference in EHL film thickness (or LP) would be expected between the two. For example, the dynamic viscosity and pressure-viscosity coefficient for lubricants of the present invention are approximately the same as for carrier fluid alone because the high viscosity fluid makes up such a small component of the lubricant. Thus, film thickness (LP) is predicted to be similar for both carrier fluid and present lubricant. However, Figures 1 and 2 display the superior film thickness, expressed as LP, of the presently described lubricants as a function of temperature and dynamic viscosity in comparison with carrier fluid alone. As film thickness typically follows LP as a function of about the 0.7 power, film thickness enhancement by the relatively small amounts of added high viscosity fluid can be up to 50% greater relative to the carrier fluid alone at any given viscosity. In order to achieve this result with standard liquid lubricants...
known in the art, approximately a 75% higher viscosity fluid at operating temperatures would be required.

In addition, the lubricants of the present invention show reduced EHL shear strength (measured as traction coefficients) relative to carrier fluid alone as measured in a Line Contact Traction Rig described in U.S. Pat. No. 5,372,033. Typically, high viscosity fluids suitable for the present invention may have lower EHL shear strengths as compared with carrier fluid alone, and shear strength behavior can be considered, to a first approximation, as a linear additive function of the shear strength properties of the components. For instance, the shear strength (SS) of a composition having components A (50% by weight), B (30% by weight), and C (20% by weight), with respective shear strengths \(a\), \(b\), and \(c\), would be the weighted average of component shear strengths as expressed in equation 2 for this particular example:

\[
SS = (0.5)a + (0.3)b + (0.2)c \quad \text{(Eq. 2)}
\]

Therefore, the relatively small amounts of high viscosity fluid in the lubricants of the present invention are expected to contribute negligibly to shear strength properties. However, as shown in Figure 3, approximately a 30% reduction in the maximum traction coefficients (shear strength) is unexpectedly observed. Therefore, lubricant compositions of the present invention preferably have lower (or reduced) shear strengths as compared with the calculated shear strength based on the weighted average of the components of the lubricant composition. In preferred embodiments, the lubricants described herein have shear strengths reduced by at least about 5%, or more preferably by at least about 15%, or even more preferably by at least about 30% as compared with the calculated shear strength for the individual components.

Also contemplated by the present invention are methods of lubrication. Specifically, encompassed is a method of lubrication comprising the steps of providing a lubricant described herein and applying the lubricant to a mechanical assembly having movable contacting surfaces. The mechanical assembly may be any machine containing surfaces that repeatedly move against each other. The mechanical assembly can have components that operate normally under hydrodynamic, elastohydrodynamic, mixed boundary and/or boundary condition or combinations of any or all of these. Preferably, the mechanical assembly operates under elastohydrodynamic lubricating conditions which involves the generation and maintenance of a lubricating film by the elastic deformation of non-conforming, contacting surfaces. Examples of mechanical assemblies that operate under elastohydrodynamic lubricating conditions include, but are not limited to, gears, rolling bearings, cams, and traction devices.

The unusual properties of the lubricants of the present invention, including greater film thickness and relatively low viscosity and shear strength, contribute to the observed superior lubricating performance. For instance, lowered shear strength and relatively low viscosities help maintain lower operating temperatures for decreased oil film breakdown and longer oil and machine component lives and improved energy efficiency. Further, reduction in shear strength contributes to reduced surface shear stress for longer machine component life involving reduced metal fatigue and higher scuffing loads. Greater film thickness benefits all aspects of lubrication, providing better protection of surfaces from reduced friction and operational wear and reducing the need for other lubricating additives to compensate for insufficient surface protection.

**EXAMPLES**

**Example 1:** Lubricants of the present invention

Presented in Table 1 are four lubricant compositions (indicated by weight percent) and their corresponding carrier composition. Selected properties are included at the bottom of the table. Both PTE fluids were derived from p-THF and i-C9 mono-acid/oleic dimer diacid and differ by kinematic viscosity (specified below). As is evidenced in this Table 1, the viscosities of the carrier fluid and the lubricants of the present invention are comparable.

<table>
<thead>
<tr>
<th>Table 1: Lubricant compositions and their properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carrier</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>PAO6 (wt%)</td>
</tr>
<tr>
<td>C16-alkyl naphthalene (wt%)</td>
</tr>
<tr>
<td>PTE1 (wt%, (kv) @ 40°C = 2250 (10^{-3}) Pa.s (cP))</td>
</tr>
<tr>
<td>PTE2 (wt%, (kv) @ 40°C = 9000 (10^{-3}) Pa.s (cP))</td>
</tr>
<tr>
<td>Kinematic viscosity ((10^{-3}) Pa.s (cp @ 40°C))</td>
</tr>
<tr>
<td>Kinematic viscosity ((10^{-3}) Pa.s (cp @ 100°C))</td>
</tr>
</tbody>
</table>
Example 2: Process description for preparation of poly-THF complex ester fluids

[0036]

Table 2: Raw materials

<table>
<thead>
<tr>
<th>Material</th>
<th>0.45kg(Lbs.)</th>
<th>Kg(Lb.)</th>
<th>Moles</th>
<th>Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly THF 250</td>
<td>404</td>
<td>1.82</td>
<td>3.64</td>
<td></td>
</tr>
<tr>
<td>Adipic acid</td>
<td>212</td>
<td>1.45</td>
<td>2.90</td>
<td></td>
</tr>
<tr>
<td>Iso-pentanoic acid</td>
<td>84</td>
<td>0.82</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Dibutyl tin oxide</td>
<td>0.10</td>
<td>Catalyst</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Xylene</td>
<td>25</td>
<td>Solvent</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

1. To a clean, dry 378 l (100 gallon) reactor, load the poly THF 250.
2. Agitator on, load adipic acid and dibutyl tin oxide.
3. Pull 0.07 Bars (50 mmHg vacuum), and re-pressurize to atmospheric pressure with nitrogen.
4. Load 11.2 kg (25 lbs.) of xylene for reflux solvent.
5. Heat to 240°C, removing about 23.4 kg (52 lbs.) water via reflux. Continue until TAN < 0.5.
6. When TAN < 0.5, cool to 150°C.
7. Load iso-pentanoic acid, and heat to 240°C. Continue reflux at 240°C until hydroxyl number is < 1.
8. When hydroxyl number < 1, pull 0.02-0.03 Bars (15-20 mmHg) vacuum and strip off excess iso-pentanoic acid. Continue stripping until TAN < 0.8. Strip should be about 3.6-4.5 kg (8-10 lbs.) iso-pentanoic acid and 11.2 kg (25 lbs.) xylene.
9. Cool to about 70°C, and add 2.25 kg (5 lbs.) of 25% aqueous sodium hydroxide solution, 0.72 Kg (1.6 lbs.) activated carbon, and 2.5 lbs. water. Mix 1 hour.
10. Pull 0.03 Bars (20 mmHg) vacuum and heat to 90°C to remove water. Hold 1 hour.
11. Break vacuum with nitrogen, and hold at 90-95°C for filtration.
12. Filter product into drums through Sparkler filter with ~2 micron filter aid coating.

Claims

1. A lubricant composition comprising a stable emulsion of
   (a) a carrier fluid comprising 10 to 90 % by weight PAOs and 10 to 90 % by weight alkylated aromatics; and
   (b) 0.01 to 10 % by weight of a higher viscosity poly-THF ester fluid having a viscosity of from 10 to 10,000 \( 10^{-6} \) m²/s (cSt) at 100°C, wherein said carrier fluid and said high viscosity fluid are substantially immiscible, said stable emulsion producing a lubricating film thickness expressed as \( LP = 10^{11} \eta_0 \eta \alpha \) wherein \( \eta_0 \) is the dynamic viscosity expressed in \( 10^{-3} \) Pa.s (cP) and \( \alpha \) is the pressure-viscosity coefficient expressed in 0.15 kPa⁻¹ (psi⁻¹) greater than the expected film thickness calculated based on the expected contribution of the two fluid components.

2. The lubricant composition of claim 1, wherein said lubricating film thickness is at least 5% greater than said expected film thickness.
3. The lubricant composition of claim 1 or 2, wherein said lubricating film thickness is at least 25% greater than said expected film thickness.

4. The lubricant composition of any of claims 1 to 3, wherein said lubricating film thickness is at least 50% greater than said expected film thickness.

5. The lubricant composition of any of claims 1 to 4, wherein the dynamic viscosity of the emulsion is not more than 10% greater than the dynamic viscosity of said carrier fluid.

6. The lubricant composition of any of claims 1 to 5, wherein the dynamic viscosity of the emulsion is not more than 5% greater than the dynamic viscosity of said carrier fluid.

7. The lubricant composition of any of claims 1 to 6, wherein the dynamic viscosity of the emulsion is not more than 1% greater than the dynamic viscosity of said carrier fluid.

8. The lubricant composition of any of claims 1 to 7, having a lower shear strength measured as traction coefficients than the calculated shear strength based on the weighted average of the components of said lubricant composition.

9. The lubricant composition of claim 8 wherein said shear strength of said emulsion is lower by at least 5% of said calculated shear strength.

10. The lubricant composition of claim 8 wherein said shear strength of said emulsion is lower by at least 15% of said calculated shear strength.

11. The lubricant composition of claim 8 wherein said shear strength of said emulsion is lower by at least 30% of said calculated shear strength.

12. The lubricant composition of any proceeding claims, wherein said lubricant composition comprises from 0.01 to 3% by weight higher viscosity fluid.

13. The lubricant composition of claim 1, wherein said carrier fluid comprises 50% to 90% by weight PAOs and 10% to 50% by weight alkylated aromatics.

14. The lubricant composition of claim 13, wherein said carrier fluid comprises 75 to 85% by weight PAOs and 15 to 25% by weight alkylated aromatics.

15. The lubricant composition of claim 1, comprising said poly-THF ester fluid in an amount of from 0.01% to 3% by weight.

16. The lubricant composition of claim 1, comprising said poly-THF ester fluid in an amount of from 0.01 to 1.6% by weight.

17. The lubricant composition of any of claims 1 to 16, further comprising at least one component selected from the group consisting of emulsifiers, rust and corrosion inhibitors, friction modifiers, metal passivators, dispersants, detergents, antioxidants, defoamants, thermal stabilizers, and extreme pressure/antiwear agents.

18. The lubricant composition of claim 1, wherein the carrier fluid comprises a blend of PAO6 and alkylated naphthalenes.

19. The lubricant composition of claim 18, wherein said carrier fluid comprises 75 to 85% by weight PAO6 and 15 to 25% by weight alkylated naphthalenes.

20. The lubricant composition of claim 18, wherein said carrier fluid comprises 80% by weight PAO6 and 20% by weight alkylated naphthalenes.

21. In the method of lubrication by applying a lubricant composition to a mechanical assembly having movable contacting surfaces, the improvement comprising applying a lubricant composition comprising an emulsion of (a) a carrier fluid; and (b) a minor amount of a higher viscosity fluid according to any of the preceding claims.

22. A method of lubrication according to claim 21, comprising the steps of:
(a) providing a lubricant composition comprising:

(i) carrier fluid comprising a blend of PA06 and alkylated naphthalenes; and
(ii) a higher viscosity poly-THF ester fluid having a viscosity of from 10 to 10,000 10⁻⁶ m²/s (cSt) wherein said ester fluid is present in the lubricant in an amount of from 0.01 to 10% by weight; and

(b) applying said lubricant composition to a mechanical assembly having movable contacting surfaces operating under elastohydrodynamic lubricating conditions.

23. A process for preparing the lubricant composition according to any of the preceding claims comprising the steps of:

(a) combining the carrier fluid and the high viscosity fluid to form a mixture, wherein said fluids are substantially immiscible;
(b) heating said mixture with agitation to a temperature at which said fluids dissolve to form a solution; and
(c) cooling said solution to a temperature at which said fluids separate into a continuous phase and a discontinuous phase to yield an emulsion.
11. Schmierstoffzusammensetzung nach Anspruch 8, bei der die Scherfestigkeit der Emulsion mindestens 30% geringer als die berechnete Scherfestigkeit ist.

12. Schmierstoffzusammensetzung nach einem der vorhergehenden Ansprüche, die 0,01 bis 3 Gew.-% einer Flüssigkeit mit höherer Viskosität enthält.


15. Schmierstoffzusammensetzung nach Anspruch 1, die die Poly-THF-Esterflüssigkeit in einer Menge von 0,01 bis 3 Gew.-% enthält.

16. Schmierstoffzusammensetzung nach Anspruch 1, die die Poly-THF-Esterflüssigkeit in einer Menge von 0,01 bis 1,6 Gew.-% enthält.


18. Schmierstoffzusammensetzung nach Anspruch 1, bei der die Trägerflüssigkeit ein Gemisch aus PAO6 und alkylierten Naphthalenen enthält.


21. Schmier verfahren zur Anwendung einer Schmierstoffzusammensetzung an einer mechanischen Gruppe mit beweglichen Kontaktoberflächen, bei dem eine Schmierstoffzusammensetzung angewendet wird, die eine Emulsion von (a) einer Trägerflüssigkeit und (b) einer geringen Menge einer Flüssigkeit mit höherer Viskosität gemäß einem der vorhergehenden Ansprüche enthält.

22. Schmierverfahren gemäß Anspruch 21, bei dem

    (a) eine Schmierstoffzusammensetzung bereitgestellt wird, die

        (i) Trägerflüssigkeit, die ein Gemisch von PAO6 und alkylierten Naphthalenen enthält, und

        (ii) eine Poly-THF-Esterflüssigkeit mit höherer Viskosität enthält, die eine Viskosität von 10 bis 10.000 10^-6 m²/s (cSt) aufweist, wobei die Esterflüssigkeit in dem Schmierstoff in einer Menge von 0,01 bis 10 Gew.-% enthalten ist, und

(b) die Schmierstoffzusammensetzung auf eine mechanische Gruppe mit beweglichen Kontaktoberflächen angewendet wird, die unter elastohydrodynamischen Schmierbedingungen betrieben wird.

23. Verfahren zur Herstellung der Schmierstoffzusammensetzung gemäß einem der vorhergehenden Ansprüche, bei dem

    (a) die Trägerflüssigkeit und die Flüssigkeit mit hoher Viskosität unter Bildung einer Mischung kombiniert werden, wobei die Flüssigkeiten im Wesentlichen unmischbar sind,

    (b) die Mischung unter Bewegung auf eine Temperatur erwärmt wird, bei der sich die Flüssigkeiten unter Bildung einer Lösung lösen, und

    (c) die Lösung auf eine Temperatur gekühlt wird, bei der sich die Flüssigkeiten in eine kontinuierliche Phase und eine diskontinuierliche Phase trennen, um eine Emulsion zu ergeben.
Revendications

1. Composition lubrifiante comprenant une émulsion stable de
   (a) un fluide porteur comprenant 10 à 90 % en poids de PAOs et 10 à 90 % en poids d’aromatiques alkylés ; et
   (b) 0,01 à 10 % en poids d’un fluide d’ester de poly-THF de viscosité supérieure ayant une viscosité allant de
   10 à 10 000 10^{-6} m^2/s (cSt) à 100°C, dans laquelle ledit fluide porteur et ledit fluide de viscosité élevée sont
   essentiellement immiscibles,

   ladite émulsion stable produisant une épaisseur de film lubrifiant exprimée par
   \[ LP = 10^{11} \eta_0 \alpha, \]
   où \( \eta_0 \) représente
   la viscosité dynamique exprimée en 10^{-3} Pa.s (cP) et \( \alpha \) représente le coefficient de pression-viscosité exprimé
   en 0,15 kPa^{-1} (psi^{-1}), supérieure à l’épaisseur de film attendue calculée à partir de la contribution attendue des
   deux constituants fluides.

2. Composition lubrifiante selon la revendication 1, dans laquelle ladite épaisseur de film lubrifiant est supérieure d’au
   moins 5 % à ladite épaisseur de film attendue.

3. Composition lubrifiante selon la revendication 1 ou 2, dans laquelle ladite épaisseur de film lubrifiant est supérieure d’au
   moins 25 % à ladite épaisseur de film attendue.

4. Composition lubrifiante selon l’une quelconque des revendications 1 à 3, dans laquelle ladite épaisseur de film
   lubrifiant est supérieure d’au moins 50 % à ladite épaisseur de film attendue.

5. Composition lubrifiante selon l’une quelconque des revendications 1 à 4, dans laquelle la viscosité dynamique de
   l’émulsion ne dépasse pas de plus de 10 % la viscosité dynamique dudit fluide porteur.

6. Composition lubrifiante selon l’une quelconque des revendications 1 à 5, dans laquelle la viscosité dynamique de
   l’émulsion ne dépasse pas de plus de 5 % la viscosité dynamique dudit fluide porteur.

7. Composition lubrifiante selon l’une quelconque des revendications 1 à 6, dans laquelle la viscosité dynamique de
   l’émulsion ne dépasse pas de plus de 1 % la viscosité dynamique dudit fluide porteur.

8. Composition lubrifiante selon l’une quelconque des revendications 1 à 7, ayant une plus faible résistance au ci-
   saillement, mesurée par les coefficients de traction, que la résistance au cisaillement calculée sur la base de la
   moyenne pondérée des constituants de ladite composition lubrifiante.

9. Composition lubrifiante selon la revendication 8 dans laquelle ladite résistance au cisaillement de ladite émulsion
   est inférieure d’au moins 5 % à ladite résistance au cisaillement calculée.

10. Composition lubrifiante selon la revendication 8 dans laquelle ladite résistance au cisaillement de ladite émulsion
    est inférieure d’au moins 15 % à ladite résistance au cisaillement calculée.

11. Composition lubrifiante selon la revendication 8 dans laquelle ladite résistance au cisaillement de ladite émulsion
    est inférieure d’au moins 30 % à ladite résistance au cisaillement calculée.

12. Composition lubrifiante selon l’une quelconque des revendications précédentes, dans laquelle ladite composition
    lubrifiante comprend de 0,01 à 3 % en poids de fluide de viscosité supérieure.

13. Composition lubrifiante selon la revendication 1, dans laquelle ledit fluide porteur comprend 50 % à 90 % en poids
    de PAOs et 10 % à 50 % en poids d’aromatiques alkylés.

14. Composition lubrifiante selon la revendication 13, dans laquelle ledit fluide porteur comprend 75 à 85 % en poids
    de PAOs et 15 à 25 % en poids d’aromatiques alkylés.

15. Composition lubrifiante selon la revendication 1, comprenant ledit fluide d’ester de poly-THF en quantité allant de
    0,01 % à 3 % en poids.

16. Composition lubrifiante selon la revendication 1, comprenant ledit fluide d’ester de poly-THF en quantité allant de
    0,01 à 1,6 % en poids.
17. Composition lubrifiante selon l’une quelconque des revendications 1 à 16, comprenant en outre au moins un constituant choisi dans le groupe constitué par les émulsifiants, les inhibiteurs de rouille et de corrosion, les modificateurs de frottement, les passivateurs de métaux, les dispersants, les détergents, les antioxydants, les antimousses, les stabilisants thermiques et les agents extrême-pression/anti-usure.

18. Composition lubrifiante selon la revendication 1, dans laquelle le fluide porteur comprend un mélange de PA06 et de naphthalènes alkylés.

19. Composition lubrifiante selon la revendication 18, dans laquelle ledit fluide porteur comprend 75 à 85 % en poids de PA06 et 15 à 25 % en poids de naphthalènes alkylés.

20. Composition lubrifiante selon la revendication 18, dans laquelle ledit fluide porteur comprend 80 % en poids de PA06 et 20 % en poids de naphthalènes alkylés.

21. Dans le procédé de lubrification consistant à appliquer une composition lubrifiante sur un assemblage mécanique ayant des surfaces de contact mobiles, l’amélioration comprenant l’application d’une composition lubrifiante comprenant une émulsion de (a) un fluide porteur ; et (b) une quantité mineure d’un fluide de viscosité supérieure selon l’une quelconque des revendications précédentes.

22. Procédé de lubrification selon la revendication 21, comprenant les étapes consistant à :

   (a) se procurer une composition lubrifiante comprenant :

       (i) un fluide porteur comprenant un mélange de PA06 et de naphthalènes alkylés ; et

       (ii) un fluide d’ester de poly-THF de viscosité supérieure ayant une viscosité allant de 10 à 10 000 10⁻⁶ m²/s (cSt), ledit fluide d’ester étant présent dans le lubrifiant en quantité allant de 0,01 à 10 % en poids ; et

   (b) appliquer ladite composition lubrifiante sur un assemblage mécanique ayant des surfaces de contact mobiles fonctionnant dans des conditions lubrifiantes élastohydrodynamiques.

23. Procédé de préparation de la composition lubrifiante selon l’une quelconque des revendications précédentes comprenant les étapes consistant à :

   (a) combiner le fluide porteur et le fluide de viscosité élevée pour former un mélange, dans lequel lesdits fluides sont essentiellement immiscibles ;

   (b) chauffer ledit mélange sous agitation à une température à laquelle lesdits fluides se dissolvent pour former une solution ; et

   (c) refroidir ladite solution à une température à laquelle lesdits fluides se séparent en une phase continue et une phase discontinue pour obtenir une émulsion.
REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

• US 4549774 A [0004]
• WO 0029522 A [0005]
• US 5602085 A [0005]
• US 5599100 A [0005]

• US 5485895 A [0005]
• US 5465810 A [0005]
• US 4041098 A [0022]
• US 5602086 A [0022]
• US 5372033 A [0032]

Non-patent literature cited in the description

• Mobil EHL Guidebook. Mobil Oil Corp, 1992 [0030]