LOW VISCOSITY FUNCTIONAL FLUIDS

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ABSTRACT

Low viscosity functional fluids are described which comprise glycols and an additive package that includes a fatty acid and a phosphate ester, such as a phosphate ester of an alkyl, alkenyl, or aryl alcohol. The fluids are particularly well-suited for use as DOT 3 or DOT 4 brake fluids and provide robust lubricity and corrosion inhibition.
LOW VISCOSITY FUNCTIONAL FLUIDS

TECHNICAL FIELD

[0001] The present application claims the benefit of the filing date of U.S. application Ser. No. 61/112,466, filed Nov. 7, 2008, which is hereby incorporated by reference for all purposes.

[0002] This disclosure relates to low viscosity functional fluids which are useful in a variety of applications, and in particular, as brake fluids.

BACKGROUND

[0003] Newly developed equipment such as electronic or automated anti-lock braking systems, stability control systems and regenerative braking systems have created a need for high performance hydraulic fluids (e.g., brake fluids) having appropriate physical and performance properties. In particular, there is a strong demand for high performance brake fluids having high lubricity to reduce or eliminate brake noise, while improving the life of the brake by reducing corrosion. The U.S. Government has developed standards that govern the designation and certification of functional fluids that are used as brake fluids using a system of DOT (Department of Transportation) designations (e.g., DOT 3, DOT 4, DOT 5.1, etc.). The standards are embodied in Federal Motor Vehicle Safety Standard 116 (“FMVSS 116”). In addition, certain standard-setting organizations such as the Society of Automotive Engineers (“SAE”) and the International Standards Organization (“ISO”) have developed their own standards and certifications for brake fluids. SAE Standard J1703 covers non-petroleum brake fluids with certain physical properties, including those shown below. SAE Standard J1704 covers “borate ester based brake fluids” that achieve a level of performance above those of the SAE J1703 standard. Similarly, ISO 4925 provides a number of brake fluid designations that are used outside of the United States, such as “Class 3,” “Class 4,” “Class 5-1,” and “Class 6.”

[0004] FMVSS 116, SAE J1703, SAE J1704, and ISO 4925 provide stringent physical property and performance requirements particularly with respect to minimum dry equilibrium reflux boiling point (ERBP), minimum wet equilibrium boiling point (WEBP), and maximum low temperature (-40°C.) viscosity. They also require maintaining adequate resistance to corrosion, stability and other specified physical properties such as pH, reserve alkalinity, rubber swell, etc. The entirety of SAE J1703 (Rev. April 2004) and J1704 (Rev. April 2004) and FMVSS 116 are hereby incorporated by reference.

[0005] The most current standards for brake fluids are set forth below:

<table>
<thead>
<tr>
<th>DOT 3, DOT 4 and DOT 5 Brake Fluid Standards</th>
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<tbody>
<tr>
<td>Standard</td>
</tr>
<tr>
<td>Classification (FMVSS, SAE)</td>
</tr>
<tr>
<td>Classification (ISO)</td>
</tr>
<tr>
<td>ERBP (max. 150°C)</td>
</tr>
<tr>
<td>Wet ERBP (3.5% water per FMVSS 116)</td>
</tr>
<tr>
<td>KINEMATIC VISCOSITY</td>
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<td></td>
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</tbody>
</table>

[0006] One exemplary solution to providing such desirable functional fluids was introduced in commonly owned U.S. Patent Application Publication 2007/0027039, entitled “Low Viscosity Functional Fluids”, and incorporated herein by reference for all purposes. Advantageously, it has been found that the desirable properties of these prior functional fluids can further be improved, in particular in the areas of lubricity and corrosion resistance. Moreover, it has been discovered that such improvements can be achieved without incurring significant cost. Even further, it may be possible to actually reduce cost through the use of new ingredients as well as prior ingredients or other alternative ingredients of such functional fluids.

[0007] Many newer brake system master cylinders include a plastic lining which is engaged by the rubber cup of the master cylinder piston when the brakes are actuated. It has been found that many known brake fluids provide insufficient lubricity in such applications, resulting in excessive noise and wear. Through the use of modified functional fluids, it may be possible to reduce such noise and wear.

[0008] FMVSS 116, J1703, J1704, and ISO 4925 each include corrosion specifications based on defined test procedures in which metal strips of various metals are submerged in a mixture of 5 percent water (by volume) and the brake fluid for a specified time (120 hours) at a specified temperature (100°C). It has been found that the FMVSS 116, J1703, J1704, and ISO 4925 standards do not reliably reproduce the actual road conditions to which many brake fluids are subjected, especially for roads in the northern climates of the U.S. which are frequently salted in the winter to control ice accumulation. As a result, it has been proposed to modify the test procedures used to evaluate corrosion by adding a chloride salt (e.g., NaCl) to the water/brake fluid mixture. However, current brake fluids are not able to provide the level of corrosion resistance required for DOT3, DOT 4, J1703, J1704 and ISO 4925 fluids when subjected to this modified test. For
example, Shannon, U.S. Pat. No. 6,558,569 and Park U.S. Pat. No. 6,339,050 describe DOT 4 brake fluids comprising alkyl glycol borate esters, alkyl glycols, and a corrosion inhibitor package. However, they do not address the issue of brake fluid contamination with salt water and provide no indication that the disclosed fluids could meet the SAE J1703/ J1704 or ISO 4925 corrosion standards when subjected to a salt water environment. Thus, a need has arisen for a functional fluid which addresses the foregoing issues.

SUMMARY

[0009] A fluid composition is provided which comprises at least one glycol and an additive package comprising at least one fatty acid and at least one phosphate ester. In certain exemplary embodiments, the at least one fatty acid is an aliphatic carboxylic acid having at least 2, preferably at least 5, more preferably at least 10, and even more preferably at least 15 carbon atoms. In other exemplary embodiments, the at least one fatty acid has no more than 35 preferably no more than 30, and even more preferably no more than 25 carbon atoms. In further exemplary embodiments, the fatty acid is monounsaturated. The fatty acids in the additive package are generally present in an amount that is at least about 0.01 percent, preferably at least about 0.04 percent, and even more preferably at least about 0.08 percent by weight of the fluid composition. The fatty acids are generally present in an amount that is no greater than about 0.4 percent, more preferably no greater than about 0.2 percent, and even more preferably no greater than about 0.15 percent by weight of the fluid composition.

[0010] The phosphate ester is generally a mono-, di- or tri-ester of an alcohol and phosphoric acid (H₃PO₄). The alcohol preferably has the formula R₃—R₄—OH, wherein R₃ is a substituted or unsubstituted alkyl, alkenyl, or aryl group having at least 2, preferably at least 3, even more preferably at least 4, and still more preferably at least 6 carbon atoms. R₄ has no more than 30, preferably no more than 28, even more preferably no more than 26, and still more preferably no more than 24 carbon atoms. R₅ is preferably an alkyl or an alkoxy group having between two and six carbon atoms. In one exemplary embodiment, R₅ is an ethoxy group (—O—CH₂—).

[0011] A fluid composition is also provided which comprises at least one glycol and an additive package, wherein when the fluid is applied between a first surface comprising a glass fiber/polyamide 66 composite and a second surface comprising an 80 Shore A hardness EPDM rubber, the coefficient of friction is less than about 0.07 after 100 seconds of sliding engagement between the first and second surfaces. In certain exemplary embodiments, the coefficient of friction is less than about 0.03 after about 100 seconds of sliding engagement. In other exemplary embodiments, the fluid has an equilibrium reflux boiling point of at least about 230°C. In other exemplary embodiments, the fluid has a kinematic viscosity of not more than about 1800 cSt at 40°C. In certain illustrative applications, the fluid is used as a master cylinder lubricant.

BRIEF DESCRIPTION OF THE FIGURES

[0012] FIG. 1 is a plot of frictional data for a first low viscosity, glycol base fluid and two modified versions of the fluid which include oleic acid and/or a phosphate ester; and FIG. 2 is a plot of frictional data for a second low viscosity, glycol base fluid and two modified versions of the fluid which include varying amounts of a phosphate ester.

DETAILED DESCRIPTION

[0014] This disclosure relates to functional fluids comprising one or more glycols and an additive package that includes at least one fatty acid and a phosphate ester. The fatty acid and phosphate ester are preferably present in an amount that is effective to aid in the lubrification frictionally engaged surfaces and to inhibit corrosion when the fluid is contaminated with salt water.

[0015] The functional fluids described herein generally comprise greater than about 20 percent by weight of total glycols, preferably greater than about 40 percent by weight of total glycols, and even more preferably greater than about 60 percent by weight of total glycols. Total glycol amounts of greater than about 70 percent are even more preferred, and total glycol amounts of greater than about 80 percent by weight are especially preferred. The total amount of glycols is preferably less than 100 percent by weight of the total functional fluid composition and is preferably no greater than about 99 percent by weight of the total fluid composition.

[0016] The glycol component can be formed partially, substantially entirely (at least 90 percent or at least 95 percent by weight) or entirely of one, two, three or more glycols, polyglycols, or both. Preferably the glycols or polyglycols of the glycol component have the formula of EQUATION I:

\[
\text{EQUATION I} \quad R_3 - R_4 \\
\text{R}_4 \text{O} \text{C} \text{C} \text{O}_3 \text{H} \\
\text{R}_3 - R_5
\]

[0017] with repeat unit:

\[
\text{EQUATION I} \quad R_3 - R_4 \\
\text{(C-C-O)} \\
\text{R}_3 - R_5
\]

[0018] Each of \( R_1, R_2, R_3, R_4 \), and \( R_5 \) is either hydrogen (H) or an alkyl group containing 1 to 8 or more carbon atoms or mixtures thereof such as one disclosed in Provisional Application Ser. No. 60/976,010 (filed Sep. 28, 2007) entitled “Functional Fluid Composition”, which is hereby incorporated by reference for all purposes. It is preferable that \( R_5 \) be an alkyl group containing 1 to 8 carbon atoms such that the glycol or polyglycol is an alkoxy glycol ether (e.g., an alkyl end capped glycol ether) as opposed to being simply a glycol where \( R_4 \) is H. Typically, \( R_5 \) is H for less than 90 percent, more typically less than 50 percent and even possibly less than 30 percent or 20 percent by weight of the glycol component, the overall fluid composition, or both. It will be understood that, as used herein, the term “polyglycol” refers to a glycol such as that of EQUATION I in which \( n \) is at least 2 or greater. The term “glycol” is inclusive of all polyglycols. It should also be understood that the glycol component can include both those glycols in which \( R_5 \) is an alkyl group and those in which \( R_5 \) is H.
The glycol component can include an amount of glycol where \( n = 1 \). When included, such glycol is less than about 5 percent by weight of the glycol component. Preferable glycols of the glycol component comprise glycols (e.g., alkoxy glycols) where \( n = 2 \), glycols (e.g., alkoxy glycols) where \( n = 3 \), glycols (e.g., alkoxy glycols) where \( n = 4 \) or more, or any mixture thereof. More preferable glycol components comprise a mixture of glycols (e.g., alkoxy glycols) having \( n = 2, n = 3, \) and \( n = 4 \) or more. It is also preferred for the glycols wherein \( n = 2 \) or more to be present in the glycol component and/or the overall functional fluid in an amount that is at least about 50 percent by weight, more preferably at least about 60 percent by weight and more preferably at about 75 percent by weight of the glycol component, the overall functional fluid or both. The amount of glycol in which \( n = 2 \) or more is even more preferably at least about 90 percent by weight.

It is also preferred for the glycols wherein \( n = 2 \) or more to be present in the glycol component and/or the overall functional fluid in an amount that is no greater than about 99 percent by weight.

The glycols in which \( n = 2 \) are preferably present in an amount that is at least about 0.5 percent by weight of the total glycol component, more preferably at least about 1 percent by weight of the total glycol component, and even more preferably at least about 2 percent by weight of the total glycol component. The glycols in which \( n = 2 \) are preferably present in an amount that is no greater than about 10 percent by weight, more preferably no greater than about 8 percent by weight, and even more preferably no greater than about 7 percent by weight of the total glycol component.

The glycols in which \( n = 3 \) are preferably present in an amount that is no greater than about 80 percent by weight of the total glycol component, more preferably no greater than about 70 percent by weight of the total glycol component, and even more preferably no greater than about 66 percent by weight of the total glycol component. The glycols in which \( n = 3 \) are preferably present in an amount that is at least about 40 percent by weight, more preferably at least about 50 percent by weight, and even more preferably at least about 58 percent by weight of the total glycol component.

The glycols in which \( n = 4 \) or greater are preferably present in an amount that is no greater than about 45 percent by weight, more preferably no greater than about 40 percent by weight, and even more preferably no greater than about 35 percent by weight of the total glycol component. The glycols in which \( n = 4 \) or greater are preferably present in an amount that is at least about 15 percent by weight, more preferably at least about 20 percent by weight, and even more preferably at least about 25 percent by weight of the total glycol component. Preferable glycol components include an \( R \) group comprising a methyl, an ethyl, a propyl, a butyl, or combinations thereof.

Without limitation, examples of useful glycols (e.g., alkoxy glycols or otherwise) include methoxy triglycol, methoxy diglycol, methoxy tetruglycol, methoxy polyglycol (e.g., mixtures of methoxy triglycol, methoxy tetraglycol, and other glycols in which \( R \) is \( CH_3 \) and \( n = 5 \) or more), ethoxy triglycol, ethoxy diglycol, ethoxy tetraglycol, propoxy triglycol, butoxy triglycol (e.g., triethylene glycol monobutyl ether), butoxy diglycol (e.g., diethylene glycol monobutyl ether), butoxy tetraglycol, butoxy polyglycol (e.g., mixtures of butoxy triglycol, butoxy tetraglycol, and other glycols in which \( R \) is an alkyl having 4 carbon atoms and \( n = 5 \) or greater), butoxy pentoxyl diglycol, pentoxy triglycol, 2-ethylhexyl diglycol and any mixture thereof.

Preferable glycols (e.g., alkoxy glycols) of the glycol component include, without limitation, methoxy triglycol, methoxy diglycol, methoxy polyglycol, methoxy tetraglycol, ethoxy polyglycol, ethoxy triglycol, ethoxy diglycol, ethoxy tetraglycol, butoxy polyglycol, butoxy triglycol, butoxy diglycol, butoxy tetraglycol, triethylene glycol monohexyl ether, diethylene glycol monopropyl ether, triethylene glycol monopropyl ether, dipropylene glycol monomethyl ether, dipropylene glycol monopropyl ether, tripropylene glycol monopropyl ether, dipropylene glycol monobutyl ether, tripropylene glycol monobutyl ether, polypropylene glycol monobutyl ether, polypropylene glycol monopropyl ether, or mixtures thereof. More preferable alkoxy glycol components comprise methoxy triglycol, methoxy diglycol, methoxy polyglycol, butoxy triglycol, butoxy diglycol, butoxy polyglycol, triethylene glycol monohexyl ether, diethylene glycol monopropyl ether, triethylene glycol monopropyl ether, dipropylene glycol monomethyl ether, dipropylene glycol monopropyl ether, tripropylene glycol monopropyl ether, dipropylene glycol monobutyl ether, tripropylene glycol monobutyl ether, polypropylene glycol monobutyl ether or mixtures thereof. Most preferable alkoxy glycol components comprise a mixture of two or more of methoxy polyglycol, butoxy diglycol, butoxy triglycol, butoxy polyglycol, triethylene glycol monopropyl ether, tripropylene glycol monopropyl ether, dipropylene glycol monobutyl ether, tripropylene glycol monobutyl ether, polypropylene glycol monobutyl ether or mixtures thereof.

Further examples of useful glycols (e.g., alkoxy glycols or the like) include, without limitation, diethylene glycol monopropyl ether, triethylene glycol monopropyl ether, dipropylene glycol monomethyl ether, dipropylene glycol monopropyl ether, tripropylene glycol monopropyl ether, dipropylene glycol monobutyl ether, tripropylene glycol monobutyl ether, polypropylene glycol monopropyl ether, polypropylene glycol monobutyl ether, polybutylene glycol monopropyl ether, polybutylene glycol monobutyl ether, combinations thereof or the like.

Without limitation, methods of preparing useful alkoxy glycols include an alkoxylation reaction that reacts an alkylene oxide with an alcohol to produce an alkoxy glycol.

The glycol component may also include a glycol polymer, which can be a homopolymer, block copolymer, random copolymer or the like. Glycol copolymers are preferred. Glycol copolymers will typically include one or more first repeat units of EQUATION 1 having a first configuration and one or more second repeat units having a second configuration. In particular, the glycol copolymer typically includes at least one of first repeat unit of EQUATION 1 wherein \( R_1, R_2, R_3, \) and \( R_4 \) are each \( H \). The glycol copolymer also typically includes at least one second repeat unit wherein at least one and typically only one, but also possibly two, three or all four of \( R_1, R_2, R_3, \) and \( R_4 \) are each an alkyl group containing 1 to 8 carbon atoms. Preferable second repeat units of the glycol copolymer include an \( R_3 \) or \( R_4 \) group and more preferably an \( R_4 \) or \( R_5 \) group comprising a methyl, an ethyl, a propyl, a butyl, or combinations thereof. More preferable second repeat units of the glycol copolymer include an \( R_3 \) or \( R_4 \) group and more preferably an \( R_4 \) or \( R_5 \) group comprising a methyl or an ethyl group. Still more preferable second repeat units of the glycol copolymer include an \( R_3 \) or \( R_4 \) group and more preferably an \( R_4 \) or \( R_5 \) group comprising a methyl group (i.e., propylene oxide repeating units).
In one exemplary embodiment, the glycol polymer has the following formula:

\[ R_1 - O - (O - PO_x EO_y O -) - R_2 \]

wherein PO is a propylene oxide unit;

EO is ethylene oxide unit;

\( R_1 \) is a hydrogen or a hydrocarbyl group;

\( R_2 \) is a hydrogen or an \( x \) valent hydrocarbyl group;

\( m \) is a number of at least 0;

\( n \) is a number of at least 0; and

\( m + n \) is greater than 0.

The glycol polymer has a molecular weight that is at least about 500 g/mol, preferably at least about 750 g/mol, and more preferably at least about 900 g/mol. The glycol polymer has a molecular weight that is no greater than about 2,000 g/mol, more preferably no greater than about 1,500 g/mol, and even more preferably no greater than about 1,110 g/mol.

In accordance with one exemplary embodiment of a glycol copolymer, \( m \) and \( n \) are equal, in which case the glycol copolymer contains equal amounts of ethylene oxide and propylene oxide repeating units. The number of repeating ethylene oxide units and the number of propylene oxide units are each preferably greater than 2, more preferably greater than 4, and even more preferably greater than 8. One suitable glycol copolymer is UCON® 50 HB-260 (The Dow Chemical Company). UCON 50 HB-260 comprises equal numbers of propylene oxide and ethylene oxide units and has a molecular weight of about 1,000 g/mol. In UCON 50 HB-260, \( R_2 \) is a univalent alkyl group, \( x \) is 1, and \( R_3 \) is a hydrogen atom.

When utilized, the glycol borate ester component preferably includes at least one ingredient having the formula:

\[ \left[R_1 O - (C - C - O)_{g} - B_2 \right] \]

with repeat unit:

\[ R_3 \]

\[ R_4 \]

\[ (C - C - O) \]

\[ R_3 \]

\[ R_4 \]

wherein \( R_1, R_2, R_3, R_4, \) and \( R_5 \) can be any of groups as specified with respect to EQUATION I and \( n \) can be as specified with respect to EQUATION I. As such, the glycol borate ester component can have any of the repeat units of glycol component as discussed with respect to EQUATION I herein. It is also understood that the glycol borate ester component and any borate containing compound is not considered as part of the glycol component, but rather is separate.

Examples of optional glycol borate ester components include alkoxyl glycol borate ester components such as methoxy triethylene glycol borate ester, ethoxy triethylene glycol borate ester, butoxy triethylene glycol borate ester and mixtures thereof disclosed in U.S. Pat. No. 6,558,569, hereby incorporated by reference. If a borate ester component is present in the composition, it is preferably present in an amount greater than about 1 percent by weight of the functional fluid. The optional borate is also preferably present in an amount that is less than about 10 percent by weight and more preferably less than about 4 percent by weight of the functional fluid. In one embodiment, the functional fluid composition is substantially free (less than about 0.5 percent by weight of the functional fluid) or entirely free of any borate ester component.

When a glycol borate ester component is included in the composition, it is typically the case that the glycol groups of the component represent a substantial portion of the overall composition. Such glycol groups, as defined herein, are the portions of EQUATION I and EQUATION II attached to the (H) hydrogen atom or the (B) Boron atom of those equations. Thus, such glycol groups are as follows:

\[ \text{EQUATION I} \]

\[ R_5 \]

\[ R_4 \]

\[ (\text{glycol group}) \]

\[ \text{EQUATION II} \]

\[ \left[R_1 O - (C - C - O)_{g} - B_2 \right] \]

\[ (\text{glycol group}) \]

These glycol groups can represent at least about 50 percent, more typically at least about 60 percent, still more typically at least about 80 percent and even possibly at least about 90 percent by weight of the overall composition.

As mentioned above, the functional fluids of the present disclosure also include an additive package which contains at least one fatty acid, at least one phosphate ester, one or more corrosion inhibitors, and one or more of the following: an antifoaming agent, a pH stabilizer, a chelating agent, and an antioxidant. The corrosion inhibitors in the additive package preferably include compounds that inhibit the corrosion of tinned iron, steel, aluminum, cast iron, brass, and copper, each of which has a corrosion specification set forth in SAE J1703, SAE J1704 and FMVSS 116. However, in an especially preferred embodiment, the corrosion inhibitors also include one or more compounds that inhibit the corrosion of zinc.

The additive package is preferably present in an amount that is at least about 0.1 percent by weight of the fluid composition, more preferably at least about 0.2 percent by weight of the fluid composition, and most preferably at least about 0.3 percent by weight of the fluid composition. The additive package is preferably present in an amount that is no greater than about 10 percent by weight of the fluid composition, more preferably no greater than about 6.0 percent by weight of the fluid composition, and most preferably no greater than about 4.0 percent by weight of the fluid composition.

The fatty acids in the additive package preferably include one or more aliphatic carboxylic acids having at least 2, preferably at least 5, more preferably at least 10, and even more preferably at least 15 carbon atoms. The aliphatic carboxylic acids generally have no more than 35, preferably no more than 30, and more preferably no more than 25 carbon atoms. Straight chain, monofunctional fatty acids are preferred, and straight chain, unsaturated, monofunctional fatty acids are more preferred. Monounsaturated fatty acids are
especially preferred. Suitable fatty acids include without limitation, oleic acid, palmitic acid, stearic acid, myristic acid, palmitoleic acid, elaidic acid, and linoelic acid. The fatty acids in the additive package are generally present in an amount that is at least about 0.01 percent, preferably at least about 0.04 percent, and more preferably at least about 0.08 percent by weight of the fluid composition. The fatty acids are generally present in an amount that is greater than or about 0.4 percent, more preferably no greater than about 0.2 percent, and most preferably no greater than about 0.15 percent by weight of the fluid composition.

[0047] One or more of the additives in the additive package will generally be a phosphate, and more specifically, a phosphate ester. The phosphate ester is generally a mono-, di- or tri-ester of an alcohol and phosphoric acid (H₃PO₄). The alcohol preferably has the following formulas:

\[ R₁—R₂—OH \]  

**EQUATION III**

[0048] wherein R₁ is a substituted or unsubstituted alkyl, alkenyl, or aryl group having at least 2, more preferably at least 3, even more preferably at least 4, and still more preferably at least 6 carbon atoms. R₂ preferably has no more than 30, more preferably no more than 28, even more preferably no more than 26, and still more preferably no more than 24 carbon atoms. R₃ is preferably an alkyl or alkoxy group having from two to six carbon atoms. In one exemplary embodiment, R₄ is an ethoxy group (—O—CH₂—CH₂—). Suitable phosphate esters include without limitation, RHODOFAC® RM-510 (Rhodia), a dinonylphenol, ethoxylated, phosphate ester, LUBRAPHOS® LP-700 (Rhodia), a phosphate ester of ethoxylated phenol, LUBRAPHOS® LB-400 (Rhodia), an ethoxylated phosphate ester of oleic alcohol, LUBRAPHOS® LK-500 (Rhodia), a phosphate ester of ethoxylated hexanol, and tricresyl phosphate, a phosphate triester of cresol.

[0049] The phosphate ester is preferably present in an amount that is at least about 0.05 percent, more preferably at least about 0.1 percent, and even more preferably at least about 0.15 percent by weight of the functional fluid. The phosphate ester is preferably present in an amount that is no greater than about 0.4 percent, more preferably no greater than about 0.3 percent, and even more preferably no greater than about 0.25 percent by weight of the functional fluid. Without wishing to be bound by any theory, and as explained further below, it is believed that the combination of the phosphate ester and the fatty acid in the functional fluid additive package produces a synergistic effect that unexpectedly improves the lubricity of the functional fluid.

[0050] The corrosion inhibitors preferably include at least one heterocyclic nitrogen-containing compound, for example, triazoles such as benzotriazole, tolytriazole, 1, 2, 4 triazole, and mixtures thereof. The triazole compounds are preferably present in an amount that is at least about 0.01 percent, more preferably at least about 0.05 percent, and most preferably at least about 0.09 percent by weight of the total fluid weight. The triazole compounds are preferably present in an amount that is no greater than about 0.4 percent, more preferably no greater than about 0.3 percent, and most preferably no greater than about 0.20 percent by weight of the total fluid composition. Without wishing to be bound by any theory, triazole compounds such as benzotriazole, tolytriazole, and 1, 2, 4 triazole are believed to be particularly effective for inhibiting copper corrosion.

[0051] The corrosion inhibitors also preferably include amine compounds other than triazoles, including alkyd amines (e.g., di-n-butylamine and di-n-amylamine), cyclohexylamine, piperazines (e.g., hydroxyethyl piperazine), and salts thereof. Non-triazole amine compounds which are particularly useful as corrosion inhibitors in the functional fluid compositions of the present disclosure include the alkanol amines, preferably those containing one to three alkanol groups with each alkanol group containing from one to six carbon atoms. Examples of useful alkanol amines include mono-, di- and trimethanolamine, mono-, di- and triethanolamine, mono-, di- and tripropanolamine and mono-, di- and triisopropanolamine. Preferred alkanol amines include butyldiethanol amine and diisopropanolamine (“diup”). Without wishing to be bound by any theory, the alkanolamines are believed to be effective for inhibiting the corrosion of ferrous compounds (e.g., iron, steel) and also act as a buffer.

[0052] The non-triazole amine compounds are preferably present in an amount that is at least about 0.1 percent, more preferably at least about 0.5 percent, and even more preferably at least about 0.8 percent by weight of the fluid composition. The non-triazole amine compounds are preferably present in an amount that is no greater than about 3 percent, more preferably no greater than about 2 percent, and most preferably no greater than about 1.5 percent by weight of the total fluid composition.

[0053] The corrosion inhibitors may include one or more alkenyl succinic anhydrides. Preferred alkenyl succinic anhydrides include derivatives of maleic anhydride. Dodeceny succinic anhydride is especially preferred. When included in the functional fluid, the alkenyl succinic anhydrides are preferably present in an amount that is at least about 0.1 percent, more preferably at least about 0.12 percent, and most preferably at least about 0.14 percent by weight of the functional fluid composition. The alkenyl succinic anhydrides are preferably present in an amount that is no greater than about 0.5 percent, more preferably no greater than about 0.3 percent, and most preferably no greater than about 0.2 percent by weight of the functional fluid composition.

[0054] In certain preferred embodiments, the corrosion inhibitors also include one or more inorganic nitrates, preferably sodium nitrate. The inorganic nitrates are preferably present in an amount that is at least about 0.01 percent, more preferably at least about 0.015 percent and most preferably at least about 0.02 percent by weight of the fluid composition. The inorganic nitrates are preferably present in an amount that is no greater than about 0.06 percent, more preferably no greater than about 0.05 percent, and most preferably no greater than about 0.04 percent by weight of the fluid composition. Without wishing to be bound by any theory, the inorganic nitrates are believed to be effective in inhibiting the corrosion of aluminum.

[0055] The corrosion inhibitors may include one or more inorganic borates such as Sodium Tetraborate, commonly known as Borax. The inorganic borates are preferably provided as solid hydrates. An especially preferred inorganic borate is sodium tetraborate pentahydrate Na₂B₄O₇·5H₂O, also known as Borax 5 Mol. Another exemplary inorganic borate is sodium tetraborate decahydrate (Na₂B₄O₇·10H₂O). When present, the inorganic borate is preferably provided in an amount that is at least about 0.03 percent, more preferably at least about 0.05 percent, and most preferably at least about 0.07 percent by weight of the fluid composition. The inorganic borate is preferably provided in an amount that is no greater than about 0.1 percent, more preferably greater than about 0.09 percent, and most preferably no greater than about 0.08 percent by weight of the fluid composition. Without wishing to be bound by any theory, the inorganic borates are believed to be effective in inhibiting ferrous corrosion (e.g., iron and steel).
[0056] The corrosion inhibitors may also optionally include one or more silicone compounds such as silicate esters. Preferred silicate esters include polymers of dialkylosiloxanes, including without limitation poly(diethoxydimethylsiloxane) (e.g., PSI-021). The silicone corrosion inhibitor is preferably provided in an amount that is at least about 0.001 percent, more preferably at least about 0.003 percent, and most preferably at least about 0.004 percent by weight of the fluid composition. The silicone corrosion inhibitor is preferably provided in an amount that is no greater than about 0.008 percent, more preferably no greater than about 0.007 percent, and most preferably no greater than about 0.006 percent by weight of the fluid composition. Without wishing to be bound by any theory, the silicone corrosion inhibitors are believed to inhibit the corrosion of brass and aluminum.

[0057] In addition to the foregoing corrosion inhibitors, the functional fluid additive package may also include other additive compounds such as anti-foaming agents, pH stabilizers, chelating agents, antioxidants, and the like. Preferred anti-foaming agents include poly(dimethylsiloxane) and silicone-based compounds such as SAG 100 Antifoam, a product of GE Advanced Materials. If present, the anti-foaming agent is preferably provided in an amount that is no greater than about 0.00020 percent and more preferably no greater than about 0.00015 percent by weight of the fluid composition. The anti-foaming agent is preferably present in an amount that is at least about 0.0001 percent and more preferably at least about 0.00005 percent by weight of the fluid composition.

[0058] Suitable antioxidants include phenolic compounds and quinoline compounds. Exemplary phenolic antioxidants include BHT (butylated hydroxytoluene); 2,6-di-tert-butyl-4-methyl phenol (which is supplied by Great Lakes Chemical Corporation under the name Lowinox® 624); 2,6-di-tet-tert-butyl-p-cresol; 2,6-di-tertary-butyl-4-sec-butylphenol (which is supplied by the SI Group under the name Isoxon® 132); and bisphenol A. Exemplary quinoline antioxidants include Agerite® Resin D, a polymerized trimethyl dihydroquinoline compound supplied by the R.T. Vanderbilt Company. If antioxidants are included in the additive package, they are preferably provided in an amount that is at least about 0.1 percent, more preferably at least about 0.2 percent, and most preferably at least about 0.25 percent by weight of the fluid composition. The antioxidants are provided in an amount that is preferably no greater than about 1.0 percent, more preferably no greater than about 0.8 percent, and most preferably no greater than about 0.4 percent by weight of the fluid composition.

[0059] Suitable chelating agents include trietylphosphine oxide, tributylphosphate, dibutyllphosphate, DEHPA (DI(2-ethylhexyl)phosphoric acid) and propandiamine/xyylene compositions such as Dupont Metal Deactivator (N.N. Disulicyclidene-1,2-propandiamine and xyylene). When used, the chelating agents are preferably present in an amount that is at least about 0.01 percent, more preferably at least about 0.05 percent, and most preferably at least about 0.08 percent by weight. The chelating agents are preferably present in an amount that is no greater than about 0.2 percent, most preferably no greater than about 0.15 percent, and most preferably no greater than about 0.13 percent by weight of the fluid composition.

[0060] As mentioned above, SAE J1703 and J1704 set forth corrosion standards for DOT 3 and DOT 4 brake fluids, respectively. In accordance with both standards, two sets of six specified metal corrosion test strips are polished, cleaned and weighed. The six metal strips comprising each set are fastened together at one end. Each strip is approximately 8 cm long, 1.3 cm wide, not more than 0.6 mm thick, and has a surface area of 25±5 cm². The specified metals are copper, brass, cast iron, aluminum, steel, and tinned iron. Two styrene-butyadiene rubber (“SBR”) cups are provided as set forth in Section 7.6 of FMVSS 116 and Appendices C and D of SAE J1704 (Rev. April 2004), and their base diameters are measured. In addition, the cups’ International Rubber Hardness Degrees (“IRHD”) values are determined using the ASTM D1415 test method, the entirety of which is incorporated herein by reference. The two SBR cups and two metal strip assemblies are placed in a jar containing the brake fluid and five (5) percent water (by volume) with the metal strip assemblies each being placed in one of the respective cups. The jar is capped and placed in an oven at 100°C for 120 hours. The strips are then removed and desiccated at 23°C ±2°C for 1 hour. Following desiccation, the strips and are each weighed to the nearest 0.1 mg and the change in weight is calculated for each strip. The area of the strips is then determined, and the weight change per unit area in mg/cm² of surface area is calculated. The diameter and IRHD values of the cups are then determined. According to FMVSS 116, in order to be certified as a DOT 4 brake fluid, the weight change per unit surface area must not exceed the following specifications, which are identical to those of SAE J1703 and J1704:

<table>
<thead>
<tr>
<th>Test Strip Material</th>
<th>Maximum weight change in mg/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel, tinned iron, cast iron</td>
<td>0.2</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.1</td>
</tr>
<tr>
<td>Brass, Copper</td>
<td>0.4</td>
</tr>
</tbody>
</table>

[0061] In addition, the SBR cup specification of FMVSS 116 calls for an inner cup diameter increase of no more than 1.4 mm and a hardness decrease of no more than 15 International Rubber Hardness Degrees. The SAE J1704 specifications are identical, except that they call for an SBR Cup volume increase of no more than 16 percent instead of specifying a diameter increase. In addition, SAE J1703 and J1704 call for a pH of not less than 7.0 and not more than 11.5 when the functional fluid is mixed with an equal volume of a 50 percent ethanol/50 percent distilled water mixture neutralized to a pH of 7.0. The standards also call for a sediment level of not more than 0.1 percent by volume. Each standard also includes a low temperature appearance requirement that calls for the absence of stratification, sedimentation, or crystallization under specified test conditions.

[0062] As mentioned above, it has been proposed to modify the brake fluid/water composition used to perform the SAE J1703 and SAE J1704 test procedures in order to better simulate the environments to which many brake fluids are subjected. In particular, many localities use road salt to keep roads free of ice and snow during the winter months. As a result, the brake fluid frequently becomes contaminated with water/salt solutions which can degrade the brake fluid's performance. In one preferred embodiment, when the functional fluids of the present disclosure are subjected to the SAE J1704 corrosion test using a mixture of brake fluid with 5 percent water (by volume) and 25 ppm chloride ion, the mixture meets the J1703/J1704 and FMVSS 116 corrosion specifications for the maximum allowable weight change per surface area for tinned iron, steel, aluminum, cast iron, brass and copper.

[0063] In addition to their corrosion inhibition properties, the fluid compositions of the present disclosure exhibit superior water stability and are able to maintain high boiling points and low viscosities at relatively high water levels. In
certain preferred embodiments, the fluid compositions maintain a wet equilibrium reflux boiling point (WERBP) of no less than about 140°C, preferably no less than about 150°C, more preferably no less than about 200°C, and even more preferably no less than about 220°C. In certain preferred embodiments, the fluid compositions maintain a dry equilibrium reflux boiling point (DERBP) of no less than about 200°C, preferably no less than about 200°C, more preferably no less than about 230°C, and even more preferably no less than about 240°C. The functional fluids preferably have a kinematic viscosity at −40°C of no greater than about 1800 cSt, more preferably no greater than about 1400 cSt, and most preferably no greater than about 1000 cSt.

EXAMPLES

Example 1

Corrosion and Lubricity Performance of a Functional Fluid with a Phosphate Ester and with a Phosphate Ester/Oleic acid Combination

In Table 3, “Methoxy polyglycol” (“MPG) refers to a mixture of methoxy triethylene glycol (10 wt. percent of the MPG) methoxy tetraethylene glycol (78.4 wt. percent of the MPG), and methoxy polyglycols with five or more repeating ethylene glycol units (10.9 wt. percent of the MPG). The LV-RG1 and LV-RG2 formulations have the following equilibrium reflux boiling points and viscosities:

<table>
<thead>
<tr>
<th>Component</th>
<th>PM6664 Base fluid</th>
<th>LV RG1 (Added phosphate ester)</th>
<th>LV RG2 (Added phosphate ester and oleic acid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyl CARBITOL</td>
<td>2.9</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Solvent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LG (Butoxy diethylene glycol)</td>
<td>53.15</td>
<td>52.33</td>
<td>52.43</td>
</tr>
<tr>
<td>Methoxy triethylene glycol</td>
<td>9.00</td>
<td>9.00</td>
<td>10.94</td>
</tr>
<tr>
<td>Butoxy triethylene glycol</td>
<td>12.00</td>
<td>12.00</td>
<td>12.00</td>
</tr>
<tr>
<td>Methoxy polyglycol</td>
<td>20.00</td>
<td>20.00</td>
<td>20.00</td>
</tr>
<tr>
<td>CUNO &amp; 50 HB 260</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CARBITOL solvent low gravity</td>
<td>0.20</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Monoethoxy glycol</td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium Nitrate</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Aug. 25, 2011
The functional fluids in Table 3 are also tested for lubricity using a Cameron-Plint Reciprocating Sliding Wear Tester in which an upper specimen comprising an 80 Durometer EPDM rubber is oscillated against a lower specimen comprising a DuPont ZYTEL®70G43 nylon 66 resin reinforced with 43 percent by weight glass fibers. The results are presented in Fig. 1 which plots the coefficient of friction versus time. As Fig. 1 indicates, both the LV-RG1 and LV-RG2 fluids achieve better lubricities (i.e., lower coefficients of friction) than the base PM6664 material after about 90 seconds. As indicated above, unlike PM 6664, both the LV-RG1 and LV-RG2 fluids include a phosphate ester. However, LV-RG2 also includes oleic acid. As Fig. 1 indicates, combining oleic acid and a phosphate ester produces more than a two-fold improvement in lubricity and a more consistent lubricity over the testing period. As Table 4 indicates, both LV-RG1 and LV-RG2 meet the ERBP specifications of both SAE J1703 (ERBP not less than 230°C) and SAE J1704 (ERBP of not less than 205°C). They also meet the -40°C kinematic viscosity specifications of both standards (not more than 1800 cSt) and the WERBP specification of SAE J1703 (not less than 140°C). In addition, even with the addition of 25 ppm chloride ion, both LV-RG1 and LV-RG2 meet the tinned iron, steel, aluminum, cast iron, brass, and copper corrosion specifications of both SAE J1703 and J1704 as well as the hardness and rubber cup diameter specifications of both standards.

### Example 2

Corrosion and Lubricity Performance of a Functional Fluid with Varying Amounts of a Phosphate Ester and without a Fatty Acid

In this example, lubricity and corrosion data are obtained for a commercial DOT 3 brake fluid (DBF 310 GC) and two modified versions of the fluid in which varying amounts of RHODOFAC® RM-510 (a dialkyl phenol ethoxylated phosphate ester) are added. The formulations are provided in Table 7:

#### Table 6

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Change in SBR Cup Diameter (mm)</th>
<th>Change in SBR Cup Hardness (IRHD)</th>
<th>Fluid appearance</th>
<th>pH after</th>
<th>Sediment (vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV-RG1</td>
<td>0.2075</td>
<td>−4.235</td>
<td>Pass</td>
<td>9.02</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LV-RG2</td>
<td>0.305</td>
<td>−4.675</td>
<td>Pass</td>
<td>8.92</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LV-RG1</td>
<td>0.1325</td>
<td>−4.175</td>
<td>Pass</td>
<td>9.01</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>LV-RG2</td>
<td>0.13</td>
<td>−3.475</td>
<td>Pass</td>
<td>8.88</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

#### Table 7

<table>
<thead>
<tr>
<th>Component</th>
<th>DBF 310 GC (Wt. %)</th>
<th>DBF 310 GC + 0.1% RM-510 (Wt. %)</th>
<th>DBF 310 GC + 0.2% RM-510 (Wt. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butoxy triethylene glycol</td>
<td>18.5</td>
<td>18.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Butoxy polyethylene glycol</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Ethoxy triethylene glycol</td>
<td>18.1</td>
<td>18.1</td>
<td>18.0</td>
</tr>
<tr>
<td>Methoxy triethylene glycol</td>
<td>14.0</td>
<td>14.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Methoxy polyethylene glycol</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Butyl Carbitol (Butoxy Diethylene Glycol)</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Diisooapropanol amine (&quot;DIPA&quot;)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Isonex</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Tolytriazole</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>1,2,4 triazole</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Sodium Nitrate</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Pusher Refined</td>
<td>14.0</td>
<td>14.0</td>
<td>14.0</td>
</tr>
<tr>
<td>SAG 100 Antifoam</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Rhodafac RM-510</td>
<td>0.10</td>
<td>0.20</td>
<td>2.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

#### Table 8

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Tinned Iron</th>
<th>Steel</th>
<th>Aluminum</th>
<th>Cast Iron</th>
<th>Brass</th>
<th>Copper</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBF 310 GC (25 ppm Cl)</td>
<td>−0.0938</td>
<td>0.0041</td>
<td>0.0163</td>
<td>0.0070</td>
<td>−0.0434</td>
<td>−0.0644</td>
<td>0.0490</td>
</tr>
</tbody>
</table>
### TABLE 8-continued

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Mass Change mg/cm²</th>
<th>Tinned Iron</th>
<th>Steel</th>
<th>Aluminum</th>
<th>Cast Iron</th>
<th>Brass</th>
<th>Copper</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBF 310 GC + 0.1% RM-510 (25 ppm Cl)</td>
<td>-0.0094</td>
<td>0.0000</td>
<td>0.0082</td>
<td>0.0105</td>
<td>-0.0162</td>
<td>-0.0362</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>DBF 310 GC + 0.1% RM-510 (0 ppm Cl)</td>
<td>-0.0067</td>
<td>0.0028</td>
<td>0.0350</td>
<td>0.0202</td>
<td>-0.0888</td>
<td>0.0776</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DBF 310 GC + 0.2% RM-510 (25 ppm Cl)</td>
<td>0.0000</td>
<td>0.0123</td>
<td>0.0122</td>
<td>0.0280</td>
<td>-0.040</td>
<td>-0.0322</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>DBF 310 GC + 0.2% RM-510 (0 ppm Cl)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 9

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Change in SBR Cup Diameter (mm)</th>
<th>Change in SBR Cup Hardness (IRHD)</th>
<th>pH</th>
<th>After Sediment (vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBF 310 GC (25 ppm Cl)</td>
<td>0.1</td>
<td>-1.6</td>
<td>9.46</td>
<td>none</td>
</tr>
<tr>
<td>DBF 310 GC + 0.1% RM-510 (25 ppm Cl)</td>
<td>0.0475</td>
<td>-1.325</td>
<td>9.28</td>
<td>0.05</td>
</tr>
<tr>
<td>DBF 310 GC + 0.1% RM-510 (0 ppm Cl)</td>
<td>0.065</td>
<td>-1.375</td>
<td>9.34</td>
<td>none</td>
</tr>
<tr>
<td>DBF 310 GC + 0.2% RM-510 (25 ppm Cl)</td>
<td>0.0275</td>
<td>-0.6</td>
<td>9.24</td>
<td>none</td>
</tr>
<tr>
<td>DBF 310 GC + 0.2% RM-510 (0 ppm Cl)</td>
<td>0.075</td>
<td>-2.025</td>
<td>9.14</td>
<td>none</td>
</tr>
</tbody>
</table>

[0071] As Tables 8 and 9 indicate, both the 0.1 percent RM-510 and 0.2 percent RM-510 formulations meet the SAE J1703/1704 corrosion specifications for tinned iron, steel, aluminum, cast iron, brass, and copper as well as the rubber cup diameter and hardness specifications of those standards.

[0072] The functional fluids of Table 7 are also tested for lubricity using the Cameron-Plint device as described previously with respect to Example 1. The surfaces used with the Cameron-Plint device are those used in Example 1. The resulting lubricity data is presented in FIG. 2. As the figure indicates, the addition of 0.1 percent of RM-510 provides for greater lubricity from 10 seconds to about 230 seconds. However, after about 230 seconds, the 0.1 percent RM-510 formulation experiences a decrease in lubricity. In contrast, the formulation with 0.2 percent RM-510 maintains a coefficient of friction below about 0.06 throughout the test period. Both formulations in Table 7 include a phosphate ester (RM-510), but neither of them includes a fatty acid. In contrast, the LV-RG2 formulation of Table 3 includes both a fatty acid and a phosphate ester. A comparison of FIGS. 1 and 2 indicates that the combination of oleic acid and RM-510 produces a substantial increase in lubricity even when the amount of RM-510 remains constant, further indicating that the combination of a fatty acid and a phosphate ester achieves a synergistic affect and an unexpected improvement in lubricity.

[0073] Functional fluids of the present disclosure are well suited for use as a hydraulic fluid for numerous mechanical systems (e.g., hydraulic lifts, cranes, forklifts, bulldozers, hydraulic jacks, brake systems, combinations thereof, or the like). The high lubricity as well as the ERBP, WERBP, and low temperature viscosity of these fluid compositions make them well-suited for brake systems in transportation vehicles (e.g., fixed and rotary wing aircraft, trains, automobiles in classes 1 to 8, or the like). These braking systems include anti-lock braking systems (ABS), stability control systems, or combinations thereof.

[0074] In one exemplary implementation, a brake system is provided which comprises a depressible actuator, a master cylinder, a piston, and a rubber cup seal disposed on the piston. The functional fluid of the present disclosure is disposed in the bore of a master cylinder and is used to transmit pressure to a braking mechanism (e.g., brake pad and rotor) to slow or stop the vehicle. As the actuator is depressed, the piston moves along the interior of the master cylinder and displaces fluid from the cylinder bore. During this operation, the rubber cup frictionally engages the walls of the master cylinder which can eventually cause the rubber cup to wear, leading to leakage around the rubber cup and diminished braking performance. In certain exemplary applications, the master cylinder is lined with plastic, and the functional fluid lubricates the frictional engagement of the rubber cup and the plastic master cylinder lining. As illustrated in FIGS. 1 and 2, the use of a functional fluid comprising at least one glycol and an additive package comprising at least one fatty acid and at least one phosphate ester beneficially reduces the amount of friction between rubber and plastic surfaces, thereby reducing the degree of wear experienced by the rubber cup.
[0075] It will be further appreciated that functions or structures of a plurality of components or steps may be combined into a single component or step, or the functions or structures of one-step or component may be split among plural steps or components. The present disclosure contemplates all of these combinations. Unless stated otherwise, dimensions and geometries of the various structures depicted herein are not intended to be restrictive of the disclosure, and other dimensions or geometries are possible. Plural structural components or steps can be provided by a single integrated structure or step. Alternatively, a single integrated structure or step might be divided into separate plural components or steps. In addition, while a feature of the present disclosure may have been described in the context of only one of the illustrated embodiments, such feature may be combined with one or more other features of other embodiments, for any given application. It will also be appreciated from the above that the fabrication of the unique structures herein and the operation thereof also constitute methods in accordance with the present disclosure.

[0076] The explanations and illustrations presented herein are intended to acquaint others skilled in the art with the disclosure, its principles, and its practical application. Those skilled in the art may adapt and apply the disclosure in its numerous forms, as may be best suited to the requirements of a particular use. Accordingly, the specific embodiments of the present disclosure as set forth are not intended as being exhaustive or limiting. The scope of the disclosure should, therefore, be determined not with reference to the above description, but should instead be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. The disclosures of all articles and references, including patent applications and publications, are incorporated by reference for all purposes.

1. A fluid composition, comprising:
   - at least one glycol; and
   - an additive package including at least one fatty acid and a phosphate ester
   wherein the at least one glycol is present in an amount that is greater than about 20 percent by weight of the total fluid composition.

2. (canceled)

3. (canceled)

4. A fluid composition in accordance with claim 1, 3, wherein the at least one glycol has the formula:

\[
\begin{array}{c}
R_1 \quad R_2 \quad R_3 \\
\downarrow \quad \downarrow \\
R_4 \quad R_5 \\
\end{array}
\]

wherein \( R_1, R_2, R_3, R_4, \) and \( R_5 \) are independently selected from the group consisting of hydrogen and an alkyl group containing 1 to 8 carbon atoms, and \( n \) is at least 1.

5. The fluid composition of claim 4, wherein the at least one glycol comprises a first glycol component in which \( n = 2 \) and a second glycol component in which \( n = 3 \).

6. A fluid composition in accordance with claim 4, wherein the at least one glycol component comprises a first glycol component in which \( R_1 \) is an alkyl group containing 1 carbon atom and a second glycol component in which \( R_1 \) is an alkyl group containing 4 carbon atoms.

7. A fluid composition in accordance with claim 1, further comprising at least one glycol borate ester present in an amount that is less than about 70 percent by weight of the fluid composition.

8. (canceled)

9. (canceled)

10. A fluid composition in accordance with claim 1, 9, wherein the at least one fatty acid is linear.

11. A fluid composition in accordance with claim 1, wherein the at least one fatty acid is monounsaturated.

12. (canceled)

13. (canceled)

14. A fluid composition in accordance with claim 1, wherein the phosphate ester is a phosphate ester of an alcohol having a formula \( R_1 \_R_2 \_OH \), wherein \( R_1 \) is selected from the group consisting of a substituted or unsubstituted alkyl, alkenyl, and aryl group, and \( R_2 \) is selected from the group consisting of an alkyl group and an alkoxy group.

15. The fluid composition of claim 14, wherein \( R_1 \) has at least 2 carbon atoms.

16. (canceled)

17. A fluid composition in accordance with claim 14, wherein \( R_1 \) is an alkyl-substituted aryl group.

18. A fluid composition in accordance with claim 14, wherein \( R_2 \) is an ethoxy group.

19. A fluid composition in accordance with claim 14, wherein \( R_1 \) is an unsubstituted alkenyl group.

20. (canceled)

21. (canceled)

22. A fluid composition in accordance with claim 1, further comprising a polyalkylene glycol having the formula:

\[
R_1 \_\text{PO}_x \_\text{EO}_y \_R_2,
\]

wherein
- \( PO \) is a propylene oxide unit;
- \( EO \) is an ethylene oxide unit;
- \( R_1 \) is a hydrogen or an x-valent hydrocarbyl group;
- \( x \) is at least 1;
- \( R_2 \) is a hydrogen or a hydrocarbyl group;
- \( m \) is a number of at least 0;
- \( n \) is a number of at least 0; and
- \( m+n \) is greater than 0.

23. (canceled)

24. (canceled)

25. (canceled)

26. (canceled)

27. (canceled)

28. (canceled)

29. (canceled)

30. (canceled)

31. A fluid composition comprising at least one glycol and an additive package, wherein when the fluid composition is applied between a first surface comprising a composite of al polyamide 66 and b) 43 percent by weight glass fiber and a second surface comprising an EPDM rubber having a shore A hardness of 80, and the first surface slidably engages the second surface, the coefficient of friction is less than about 0.07 after 100 seconds of sliding engagement between the first and second surfaces.

32. The fluid composition of claim 31, wherein the coefficient of friction is less than about 0.03 after 100 seconds of sliding engagement between the first and second surfaces.

33. (canceled)
34. (canceled)
35. (canceled)
36. A fluid composition in accordance with claim 31, wherein the at least one glycol has the formula:

\[
R_1(R_2)O-\overset{O}{\overline{C}}-\overset{O}{\overline{C}}-O_nH,
\]

wherein
R₁, R₂, R₃, R₄, and R₅ are independently selected from the group consisting of hydrogen and an alkyl group containing 1 to 8 carbon atoms, and n is at least 1.

37. The fluid composition of claim 36, wherein the at least one glycol comprises a first glycol component in which n=2 and a second glycol component in which n=3.

38. A fluid composition in accordance with claim 36, wherein the at least one glycol component comprises a first glycol component in which R₁ is an alkyl group containing 1 carbon atom and a second glycol component in which R₃ is an alkyl group containing 4 carbon atoms.

39. A fluid composition in accordance with claim 31, further comprising at least one glycol borate ester present in an amount that is not greater than about 70 percent by weight of the fluid composition.

40. A fluid composition in accordance with claim 31, further comprising at least one polyalkylene glycol having the formula:

\[
R_1(R_2)O-(PO)_{m}(EO)_{n}-R_3,
\]

wherein PO is a propylene oxide unit; EO is an ethylene oxide unit; R₃ is hydrogen or a hydrocarbyl group; x is at least 1; R₄ is hydrogen or an x valent hydrocarbyl group; m is a number of at least 0; n is a number of at least 0; and m+n is greater than 0.

41. (canceled)
42. (canceled)
43. (canceled)
44. (canceled)
45. (canceled)

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