

ELECTRIC VEHICLE FLUIDS

FIELD OF THE DISCLOSURE

[0001] The present disclosure relates to lubricant additive compositions and lubricating oil compositions containing the same. More particularly, the compositions provide improved protection against wear, friction, and/or fatigue in electric vehicles.

BACKGROUND

[0002] Wear, friction, and/or fatigue can be a major problem for traditional internal combustion engines. The same can also be a major problem in vehicles (e.g., electric vehicles or hybrid vehicles) utilizing electric motors which rely on planetary gears. Unlike traditional vehicles, electric and/or hybrid vehicles present some unique challenges, particularly since the same lubricating fluid is often shared by the electric motor and the transmission.

SUMMARY OF THE INVENTION

[0003] In one aspect, this disclosure relates to an electric driveline fluid comprising: (a) a major amount of an oil of lubricating viscosity; (b) an electric driveline additive comprising glycerol, glycol, glycol ether, pentaerythritol, vicinal diol, triol, or a derivative thereof; and (c) at least one overbased sulfonate detergent; wherein the amount of the electric driveline additive is from about 0.001 wt. % to about 1.5 wt. % based on the total weight of the electric driveline fluid.

[0004] In another aspect, this disclosure relates to a method of improving the wear, friction, or fatigue performance of an engine featuring an electric driveline, the method comprising lubricating the engine with an electric driveline fluid comprising: (a) a major amount of an oil of lubricating viscosity; (b) an electric driveline additive comprising glycerol, glycol, glycol ether, pentaerythritol, vicinal diol, triol, or a derivative thereof; and (c) at least one overbased sulfonate detergent; wherein the amount of the electric driveline additive is from about 0.001 wt. % to about 1.5 wt. % based on the total weight of the electric driveline fluid.

DETAILED DESCRIPTION

Definitions

[0005] The following terms will be used throughout the specification and will have the following meanings unless otherwise indicated.

[0006] The term "a major amount" of a base oil refers to where the amount of the base oil is at least 40 wt. % of the lubricating oil composition. In some embodiments, "a major amount" of a base oil refers to an amount of the base oil more than 50 wt. %, more than 60 wt. %, more than 70 wt. %, more than 80 wt. %, or more than 90 wt. % of the lubricating oil composition.

[0007] "HOB" refers to high overbased with a TBN above 250 on an active basis and "LOB" refers to low overbased with a TBN below 100 on an active basis.

[0008] The term "Total Base Number" or "TBN" refers to the level of alkalinity in an oil sample, which indicates the ability of the composition to continue to neutralize corrosive acids, in accordance with ASTM Standard No. D2896 or equivalent procedure. The test measures the change in electrical conductivity, and the results are expressed as mgKOH/g (the equivalent number of milligrams of KOH needed to neutralize 1 gram of a product). Therefore, a high TBN reflects strongly overbased products and, as a result, a higher base reserve for neutralizing acids.

[0009] As used herein, an EV fluid refers to an electric drive fluid used in electric vehicles equipped with wet EV motors. Electric drive fluids are analogous to transmission fluids (used in conventional vehicles) but with, usually, one or more added functionalities (e.g., acting as a coolant for the EV motor, providing electrical resistivity, etc.). The one or more added functionalities can provide unique challenges to formulating EV fluids.

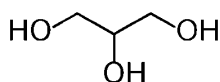
[0010] The present application relates to a lubricant additive (electric driveline additive) and/or lubricating oil composition (e.g., electric driveline fluid) containing the same. The composition(s) are suitable for use in a vehicle comprising an electric driveline (i.e., vehicle equipped with an electric motor). More particularly, the lubricating oil composition includes a lubricant additive and a high overbased sulfonate detergent. As an advantage, the compositions exhibit enhanced protection against fatigue, wear, and/or friction.

[0011] In some embodiments, the lubricating oil composition of the present invention can provide protection against fatigue, wear, and/or friction in hybrid vehicles or plug-in hybrid vehicles which are equipped with electric motors.

Electric Driveline Additive

[0012] The lubricating oil composition of this disclosure includes an electric driveline additive. The electric driveline additive includes glycerol, derivatives of glycerol, glycols, glycol ethers, pentaerythritol, derivatives of pentaerythritol, vicinal diols, triols, or cyclic derivatives thereof.

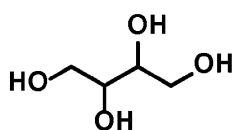
[0013] Glycerol and Derivatives



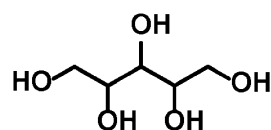
Glycerol

[0014] A compound may be considered a derivative of glycerol if it includes 2 or more 1,2 diol structure motifs. In some embodiments, the derivative of glycerol is made of 24 carbons or less, such as 23 carbons or less, 22 carbons or less, 21 carbons or less, 20 carbons or less, 19 carbons or less, 18 carbons or less, 17 carbons or less, 16 carbons or less, or 15 carbons or less.

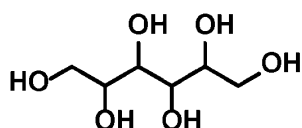
[0015] Specific examples of derivatives of glycerol include, but are not limited to, erythritol (Structure A1), xylitol (Structure A2), sorbitol (Structure A3), diglycerol (Structure A4), and triglycerol (Structure A5).



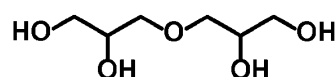
Structure A1



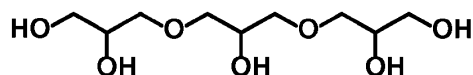
Structure A2



Structure A3



Structure A4



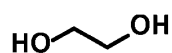
Structure A5

Glycols or Glycol Ethers

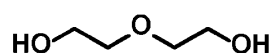
[0016] A glycol is a polyol wherein at least 2 hydroxy (-OH) groups are attached to different carbon atoms. A glycol ether is an alkyl ether that is based on a glycol.

[0017] In some embodiments, the glycol or glycol ether is made of 24 carbons or less, such as 23 carbons or less, 22 carbons or less, 21 carbons or less, 20 carbons or less, 19 carbons or less, 18 carbons or less, 17 carbons or less, 16 carbons or less, or 15 carbons or less.

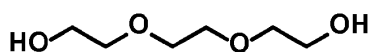
[0018] Specific examples of glycols or glycol ethers include, for example, ethylene glycol (Structure B1), diethylene glycol (Structure B2), triethylene glycol (Structure B3), 1,3 propylene glycol (Structure B4), and ethylene glycol monomethylether (Structure B5).



Structure B1



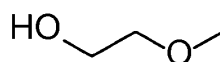
Structure B2



Structure B3

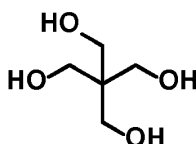


Structure B4



Structure B5

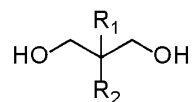
Pentaerythritol and Derivatives



Pentaerythritol

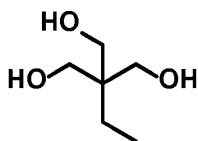
[0019] Pentaerythritol (shown above) has 4 -OH groups and a quaternary carbon at the center of the molecule.

[0020] Derivatives of pentaerythritol (shown below) may have the following generalized structure, wherein R_1 and R_2 are independently hydrocarbyl groups, or hydrocarbyl alcohols having 5 or less carbons.

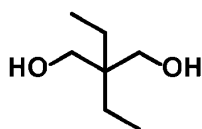


Derivative of Pentaerythritol

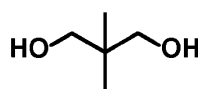
[0021] Derivatives of pentaerythritol include, for example, 1,1,1-tris(hydroxymethyl)propane (Structure C1), 2,2-diethyl-1,3 propanediol (Structure C2, and 2,2-dimethyl-1,3 propanediol (Structure C3).



Structure C1



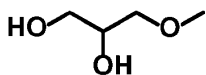
Structure C2



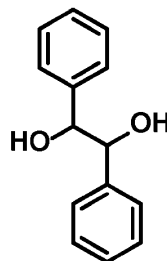
Structure C3

Vicinal Diols

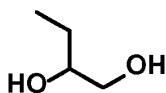
[0022] Vicinal diols include, for example, ethanediols, propanediols, butanediols, pentanediols, hexanediols, heptanediols, and the like. Specific examples of vicinal diols include 3-methoxy-1,2-propanediol (Structure D1), 1,2-diphenyl-1,2-ethanediol (Structure D2), 1,2-butanediol (Structure D3), 2,3-butanediol (Structure D4), pinacol (Structure D5), and 1-phenyl-1,2-ethanediol (Structure D6).



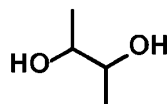
Structure D1



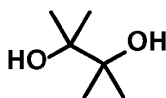
Structure D2



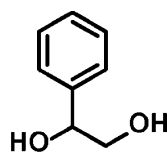
Structure D3



Structure D4



Structure D5

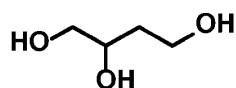


Structure D6

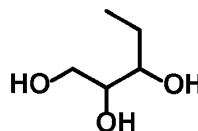
Triols

[0023] A triol has 3 -OH groups. In some embodiments, the triol has at least one vicinal diol moiety.

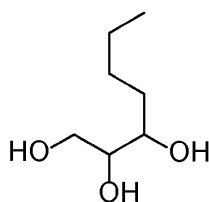
[0024] Specific triols include, for example, butanetriols, pentanetriols, hexanetriols, heptanetriols, and the like. Specific examples of triols include 1,2,4-butanetriol (Structure E1), pentane-1,2,3-triol (Structure E2), and heptane-1,2,3-triol (Structure E3).



Structure E1



Structure E2



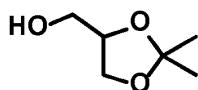
Structure E3

Cyclic Derivatives

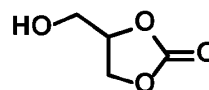
[0025] In some embodiments, the electric driveline additive includes a cyclic derivative. Specific examples of cyclic derivatives include, for example, solketal (Structure H1), and glycerol carbonate (Structure H2). H1 can be formed via a condensation reaction of glycerol with ketal (e.g., acetone). H2 can be formed, for example, via a condensation

reaction of glycerol with carbon dioxide or via a transesterification with dimethyl carbonate. Similar condensation reactions are also possible with aldehydes to form acetals. In some embodiments, the cyclic derivative has a 5-, 6-, 7-, or 8-membered ring.

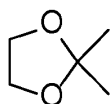
[0026] Other cyclic derivatives include cyclic derivatives of any of the aforementioned electric driveline additives such as ethylene glycol (derivatives include Structures H3-H5), 3-methoxy-1,2-propanediol (derivatives include Structures H6 and H7).



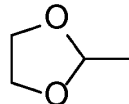
Structure H1



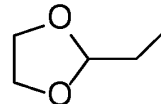
Structure H2



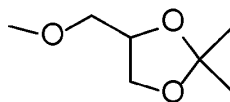
Structure H3



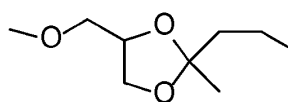
Structure H4



Structure H5



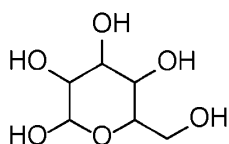
Structure H6



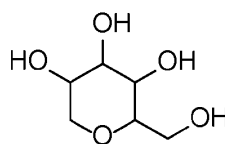
Structure H7

[0027] Other cyclic derivatives include derivatives of 1,2-butanediol, 2,3-butanediol, pinacol, 1-phenyl-1,2-ethanediol, 1,2-diphenyl-1,2-ethanediol, 1,2,4-butanetriol, 1,2,3-heptanetriol, and so forth.

[0028] Cyclic derivatives can include closed forms of sugar monomers (e.g., pentose, hexose). Structure I1 and I2 are illustrative non-limiting sugar monomers. Specific examples of sugar monomers include sorbitol, mannose, glucose, and the like. For example, sorbitol (Structure A3) can also exist in a closed form (Structure I2). Structure I2 or 1,5-anhydro-D-sorbitol is the condensation product of sorbitol.



Structure I1



Structure I2

[0029] Without being limited by theory, it is believed that the chirality of one or more carbon atoms of each additive compound can greatly impact its performance.

[0030] The exact amount of the electric driveline additive may vary depending upon the specific composition and amount of the oil or lubricating viscosity, the specific detergents and amounts, and the other desired properties of the lubricating oil composition. In some embodiments the amount of electric driveline additive is at least about 0.001 wt.% based on the total lubricating oil composition, or at least about 0.05 wt.%, or at least about 0.1 wt.%, or at least about 0.3 wt.%, or at least about 0.4 wt.%, or at least about 0.4 wt.%, or at least about 0.5 wt.%, or at least about 0.75 wt.%, or at least

about 1.0 wt. % up to about 1.5 wt.%, or up to about 1.25 wt.%, or up to about 1.0 wt.%, or up to about 0.9 wt.%, or up to about 0.8 wt. % based on the total weight of the lubricating oil composition.

Detergents

[0031] The lubricating oil composition comprises a metal sulfonate detergent. The metal can be any metal suitable for making sulfonate detergents. Non-limiting examples of suitable metals include alkali metals, alkaline earth metals and transition metals. In some embodiments, the metal is Ca, Mg, Ba, K, Na, Li or the like.

[0032] Generally, the amount of the detergent is from about 0.001 wt. % to about 10 wt. %, from about 0.05 wt. % to about 3 wt. %, or from about 0.1 wt. % to about 1 wt. %, based on the total weight of the lubricating oil composition.

[0033] Optionally, the lubricating oil composition may comprise additional detergents generally known in the art. Some suitable detergents have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapter 3, pages 75-85 (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker, Chapter 4, pages 113-136 (2003), both of which are incorporated herein by reference. Examples of these detergents include phenates, salicylates, phosphonates, and the like.

[0034] In some embodiments the detergent comprises at least one high overbased (TBN above 250 on an actives basis) sulfonate detergent such as high overbased calcium sulfonate.

[0035] Overbased metal detergents are generally produced by carbonating a mixture of hydrocarbons, detergent acid, for example: sulfonic acid, alkylhydroxybenzoate etc., metal oxide or hydroxides (for example calcium oxide or calcium hydroxide) and promoters such as xylene, methanol and water. For example, for preparing an overbased calcium sulfonate, in carbonation, the calcium oxide or hydroxide reacts with the gaseous carbon dioxide to form calcium carbonate. The sulfonic acid is neutralized with an excess of CaO or Ca(OH)₂, to form the sulfonate.

[0036] Generally speaking, overbased detergents may be low overbased (LOB), e.g., an overbased salt having a TBN below 100 on an actives basis. In one aspect, the TBN of a low overbased salt may be from about 10 to about 100. In another aspect, the TBN of a low overbased salt may be from about 10 to about 80. Overbased detergents may be medium overbased (MOB), e.g., an overbased salt having a TBN from about 100 to about 250 on an actives basis. In one aspect, the TBN of a medium overbased salt may be from about 100 to about 200. In another aspect, the TBN of a medium overbased salt may be from about 125 to about 175. Overbased detergents may be high overbased (HOB), e.g., an overbased salt having a TBN above 250 on an actives basis. In one aspect, the TBN of a high overbased salt may be from about 250 to about 800 on an actives basis.

Other Additives

[0037] Optionally, the lubricating oil composition may further comprise at least an additive or a modifier (hereinafter designated as "additive") that can impart or improve any desirable property of the lubricating oil composition. Any additive known to a person of ordinary skill in the art may be used in the lubricating oil compositions disclosed herein. Some suitable additives have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition. London, Springer, (1996); and Leslie R. Rudnick, "Lubricant Additives: Chemistry and Applications," New York, Marcel Dekker (2003), both of which are incorporated herein by reference. In some embodiments, the additive can be selected from the group consisting of antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, multi-functional additives, viscosity index improvers, pour point depressants, foam inhibitors, metal deactivators, dispersants, corrosion inhibitors, lubricity improvers, thermal stability improvers, anti-haze additives, icing inhibitors, dyes, markers, static dissipaters, biocides and combinations thereof.

[0038] In general, the concentration of each of the additives in the lubricating oil composition, when used, may range from about 0.001 wt. % to about 10 wt. %, from about 0.01 wt. % to about 5 wt. %, or from about 0.1 wt. % to about 2.5 wt. %, based on the total weight of the lubricating oil composition. Further, the total amount of the additives in the lubricating oil composition may range from about 0.001 wt. % to about 20 wt. %, from

about 0.01 wt. % to about 10 wt. %, or from about 0.1 wt. % to about 5 wt. %, based on the total weight of the lubricating oil composition.

[0039] In some embodiments, the electric driveline fluid is substantially free of sulfur-containing zinc compounds such as zinc dialkyl dithiophosphate. In some embodiments, the sulfur-containing zinc compound is present in an amount that contributes 100 ppm or less of zinc by total weight of the electric driveline fluid. In some embodiments, the electric driveline fluid contains less than 100 ppm of zinc by total weight of the electric driveline fluid.

The Oil of Lubricating Viscosity

[0040] The lubricating oil compositions disclosed herein generally comprise at least one oil of lubricating viscosity. Any base oil known to a skilled artisan can be used as the oil of lubricating viscosity disclosed herein. Some base oils suitable for preparing the lubricating oil compositions have been described in Mortier et al., "Chemistry and Technology of Lubricants," 2nd Edition, London, Springer, Chapters 1 and 2 (1996); and A. Sequeria, Jr., "Lubricant Base Oil and Wax Processing," New York, Marcel Decker, Chapter 6, (1994); and D. V. Brock, Lubrication Engineering, Vol. 43, pages 184-5, (1987), all of which are incorporated herein by reference. Generally, the amount of the base oil in the lubricating oil composition may be from about 70 to about 99.5 wt. %, based on the total weight of the lubricating oil composition. In some embodiments, the amount of the base oil in the lubricating oil composition is from about 75 to about 99 wt. %, from about 80

to about 98.5 wt. %, or from about 80 to about 98 wt. %, based on the total weight of the lubricating oil composition.

[0041] In certain embodiments, the base oil is or comprises any natural or synthetic lubricating base oil fraction. Some non-limiting examples of synthetic oils include oils, such as polyalphaolefins or PAOs, prepared from the polymerization of at least one alpha-olefin, such as ethylene, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases, such as the Fisher-Tropsch process. In certain embodiments, the base oil comprises less than about 10 wt. % of one or more heavy fractions, based on the total weight of the base oil. A heavy fraction refers to a lube oil fraction having a viscosity of at least about 20 cSt at 100° C. In certain embodiments, the heavy fraction has a viscosity of at least about 25 cSt or at least about 30 cSt at 100° C. In further embodiments, the amount of the one or more heavy fractions in the base oil is less than about 10 wt. %, less than about 5 wt. %, less than about 2.5 wt. %, less than about 1 wt. %, or less than about 0.1 wt. %, based on the total weight of the base oil. In still further embodiments, the base oil comprises no heavy fraction.

[0042] In certain embodiments, the lubricating oil compositions comprise a major amount of a base oil of lubricating viscosity. In some embodiments, the base oil has a kinematic viscosity at 100° C. from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 centistokes (cSt) to about 20 cSt, or from about 5 cSt to about 16 cSt. The kinematic

viscosity of the base oils or the lubricating oil compositions disclosed herein can be measured according to ASTM D 445, which is incorporated herein by reference.

[0043] In other embodiments, the base oil is or comprises a base stock or blend of base stocks. In further embodiments, the base stocks are manufactured using a variety of different processes including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. In some embodiments, the base stocks comprise a rerefined stock. In further embodiments, the rerefined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use.

[0044] In some embodiments, the base oil comprises one or more of the base stocks in one or more of Groups I-V as specified in the American Petroleum Institute (API) Publication 1509, Fourteen Edition, December 1996 (i.e., API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils), which is incorporated herein by reference. The API guideline defines a base stock as a lubricant component that may be manufactured using a variety of different processes. Groups I, II and III base stocks are mineral oils, each with specific ranges of the amount of saturates, sulfur content and viscosity index. Group IV base stocks are polyalphaolefins (PAO). Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

[0045] In some embodiments, the base oil comprises one or more of the base stocks in Group I, II, III, IV, V or a combination thereof. In other embodiments, the base oil

comprises one or more of the base stocks in Group II, III, IV or a combination thereof. In further embodiments, the base oil comprises one or more of the base stocks in Group II, III, IV or a combination thereof wherein the base oil has a kinematic viscosity from about 2.5 centistokes (cSt) to about 20 cSt, from about 4 cSt to about 20 cSt, or from about 5 cSt to about 16 cSt at 100° C.

[0046] The base oil may be selected from the group consisting of natural oils of lubricating viscosity, synthetic oils of lubricating viscosity and mixtures thereof. In some embodiments, the base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocrackate base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. In other embodiments, the base oil of lubricating viscosity includes natural oils, such as animal oils, vegetable oils, mineral oils (e.g., liquid petroleum oils and solvent treated or acid-treated mineral oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types), oils derived from coal or shale, and combinations thereof. Some non-limiting examples of animal oils include bone oil, lanolin, fish oil, lard oil, dolphin oil, seal oil, shark oil, tallow oil, and whale oil. Some non-limiting examples of vegetable oils include castor oil, olive oil, peanut oil, rapeseed oil, corn oil, sesame oil, cottonseed oil, soybean oil, sunflower oil, safflower oil, hemp oil, linseed oil, tung oil, oiticica oil, jojoba oil, and meadow foam oil. Such oils may be partially or fully hydrogenated.

[0047] In some embodiments, the synthetic oils of lubricating viscosity include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and inter-polymerized olefins, alkylbenzenes, polyphenyls, alkylated diphenyl ethers, alkylated diphenyl sulfides, as well as their derivatives, analogues and homologues thereof, and the like. In other embodiments, the synthetic oils include alkylene oxide polymers, interpolymers, copolymers and derivatives thereof wherein the terminal hydroxyl groups can be modified by esterification, etherification, and the like. In further embodiments, the synthetic oils include the esters of dicarboxylic acids with a variety of alcohols. In certain embodiments, the synthetic oils include esters made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers. In further embodiments, the synthetic oils include tri-alkyl phosphate ester oils, such as tri-n-butyl phosphate and tri-iso-butyl phosphate.

[0048] In some embodiments, the synthetic oils of lubricating viscosity include silicon-based oils (such as the polyakyl-, polyaryl-, polyalkoxy-, polyaryloxy-siloxane oils and silicate oils). In other embodiments, the synthetic oils include liquid esters of phosphorus-containing acids, polymeric tetrahydrofurans, polyalphaolefins, and the like.

[0049] Base oil derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base oil. Such wax isomerate oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

[0050] In further embodiments, the base oil comprises a poly-alpha-olefin (PAO). In general, the poly-alpha-olefins may be derived from an alpha-olefin having from about 2 to about 30, from about 4 to about 20, or from about 6 to about 16 carbon atoms. Non-limiting examples of suitable poly-alpha-olefins include those derived from octene, decene, mixtures thereof, and the like. These poly-alpha-olefins may have a viscosity from about 2 to about 15, from about 3 to about 12, or from about 4 to about 8 centistokes at 100° C. In some instances, the poly-alpha-olefins may be used together with other base oils such as mineral oils.

[0051] In further embodiments, the base oil comprises a polyalkylene glycol or a polyalkylene glycol derivative, where the terminal hydroxyl groups of the polyalkylene glycol may be modified by esterification, etherification, acetylation and the like. Non-limiting examples of suitable polyalkylene glycols include polyethylene glycol, polypropylene glycol, polyisopropylene glycol, and combinations thereof. Non-limiting examples of suitable polyalkylene glycol derivatives include ethers of polyalkylene glycols (e.g., methyl ether of polyisopropylene glycol, diphenyl ether of polyethylene glycol, diethyl ether of polypropylene glycol, etc.), mono- and polycarboxylic esters of polyalkylene glycols, and combinations thereof. In some instances, the polyalkylene glycol or polyalkylene glycol derivative may be used together with other base oils such as poly-alpha-olefins and mineral oils.

[0052] In further embodiments, the base oil comprises any of the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, and the like) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, and the like). Non-limiting examples of these esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the like.

[0053] In further embodiments, the base oil comprises a hydrocarbon prepared by the Fischer-Tropsch process. The Fischer-Tropsch process prepares hydrocarbons from gases containing hydrogen and carbon monoxide using a Fischer-Tropsch catalyst. These hydrocarbons may require further processing in order to be useful as base oils. For example, the hydrocarbons may be dewaxed, hydroisomerized, and/or hydrocracked using processes known to a person of ordinary skill in the art.

[0054] In further embodiments, the base oil comprises an unrefined oil, a refined oil, a rerefined oil, or a mixture thereof. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. Non-limiting examples of unrefined oils include shale oils obtained directly from retorting operations, petroleum

oils obtained directly from primary distillation, and ester oils obtained directly from an esterification process and used without further treatment. Refined oils are similar to the unrefined oils except the former have been further treated by one or more purification processes to improve one or more properties. Many such purification processes are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, and the like. Rerefined oils are obtained by applying to refined oils processes similar to those used to obtain refined oils. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally treated by processes directed to removal of spent additives and oil breakdown products.

[0055] The following examples are presented to exemplify embodiments but are not intended to limit the application to the specific embodiments set forth. Unless indicated to the contrary, all parts and percentages are by weight. All numerical values are approximate. When numerical ranges are given, it should be understood that embodiments outside the stated ranges may still fall within the scope of the application. Specific details described in each example should not be construed as necessary features.

EXAMPLES

[0056] The following examples are intended for illustrative purposes only and do not limit in any way the scope. Inventive and comparative oil samples were subjected to the following performance tests.

Shell 4-ball wear test

[0057] The antiwear performance of each lubricating oil compositions was determined in accordance with the 4-ball wear scar test ASTM D4172 under conditions of 1200 rpm, oil temperature of 60°C, and a load of 40 kgf for 60 min. After testing, the test balls were removed, and the wear scars were measured. The wear scar diameters are reported in Table 1. A smaller wear scar diameter indicates better antiwear performance.

High Frequency Reciprocating Rig (HFRR) Wear Test

[0058] Friction coefficients were measured by a High Frequency Reciprocating Rig (HFRR) test. The test equipment and procedure are similar to the ASTM D6079 method except the test oil temperature is raised from 32° C to 110° C. at 2° C./minute, 500 g load, 20 Hz frequency for 1 hour. The test can measure average friction coefficient and wear volume.

ZF Bearing Pitting Test

[0059] Bearing performance is evaluated using ZF specification 03C bearing pitting test 0000 702 232. This test uses FE 8 roller thrust bearings with an axial for of 68 kN revolving at 300 rpm. The temperature is 100 °C. In this test, the length of time to failure is measured and failure is determined when vibration becomes so severe that metal pieces get dislodged from the bearing or the case that contacts the bearing and the FE8 test rig

automatically shuts down. The removed metal leaves pits in the bearing or the case. In order to pass the test for the ZF 03C specification, the minimal length of time to failure is 300 hours. The maximum amount of time the test is allowed to run is 750 hours. The ZF bearing pitting test is available from Assmann Laboratories, Aachen, Germany.

[0060] Bearing performance is evaluated using ZF specification 03C bearing pitting test. In this test, the length of time to failure is measured and failure is determined when vibration becomes so severe that metal pieces get dislodged from the bearing or the case that contacts the bearing and the FE8 test rig automatically shuts down. In order to pass the test, the minimal length of time to failure is 300 hours. The maximum amount of time the test is allowed to run is 750 hours. The ZF bearing pitting test is available from Assmann Laboratories, Aachen, Germany.

[0061] The compositions of **Examples 1-26** were evaluated using the Four-Ball and HFRR wear tests.

[0062] The results for the Four-Ball and HFRR wear tests are summarized below in Table 1.

TABLE 1¹

Example	Additive	Four Ball ² (mm)	HFRR ² (mm)	HFRR (CoF) ¹
1	Glycerol	375	220	0.103
2	Erythritol	450	284	0.171
3	Xylitol	522	308	0.177

4	Sorbitol	554	314	0.165
5	Diglycerol	482	270	0.133
6	Triglycerol	430	277	0.166
7	3-Methoxy-1,2-propanediol	350	298	0.167
8	1,2,4-Butanetriol	326	247	0.110
9	Pentaerythritol	482	248	0.096
10	1,1,1-Tris(hydroxymethyl)propane	500	310	0.179
11	2,2-Diethyl-1,3-propanediol	489	349	0.183
12	Ethylene Glycol	328	217	0.091
13	Diethylene Glycol	538	287	0.162
14	Triethylene Glycol	530	329	0.148
15	2,2-Dimethyl-1,3-propanediol	452	258	0.169
16	1,3-Propanediol	514	303	0.167
17	1,2-Butanediol	523	263	0.092
18	2,3-Butanediol	404	252	0.083
19	Pinacol	457	262	0.0905
20	1-Phenyl-1,2-ethanediol	362	316	0.141
21	meso-1,2-Diphenyl-1,2-ethanediol	312	299	0.124

22	1,2,3-heptanetriol	449	312	0.171
23	Glycerol Carbonate	351	274	0.168
24	Solketal	419	N/A	0.112
25	3-Amino-1,2-propanediol	351	248	0.107
26	Tetraethylenepentamine	428	310	0.141

¹ 60mM HOB Sulfonate, 0.1 wt. % glycerol derivative, and Base Oil

² Average 4-Ball: 40kgf, 60°C, 1200 RPM, 60 Minutes

³ Average HFRR: 60min, 20Hz, 1mm, 110°C, 500g

⁴ EOT Friction Average (Last 15 Minutes)

[0063] The compositions of **Examples 27-38** were evaluated using the ZF bearing pitting test. The results for the ZF bearing test are summarized below in Table 2.

Table 2¹

Example	Glycerol or Glycerol Derivative	ZF FE8 ⁵
27	Glycerol	750
28	Erythritol	750
29	Diglycerol	572.5
30	Triglycerol	430

31	1,2,4-Butanetriol	750
32	Pentaerythritol	482
33	Diethylene Glycol	348.5
34	1,2-Propanediol	750
35	2,2-Dimethyl-1,3-propanediol	452
36	1,3-Propanediol	747.5
37	2,3-Butanediol	705.5
38	3-Amino-1,2-propanediol	629.5

⁵Bearing Pitting, Average Hours to Failure

[0064] As shown in Table 2, the ZF Bearing Pitting results (ZF FE8) of **Examples 27-38**, demonstrate the effectiveness of the electric driveline additives to pass the bearing pitting test.

[0065] The compositions of **Examples 39-49** were evaluated using the Four Ball test. The results are summarized below in Table 3.

Table 3⁷

Example	Glycerol Derivative	Wt.%	Four Ball ⁶ (mm)
39	Glycerol	0.01	330
40	Glycerol	1.0	313
41	1,2,4-Butanetriol	0.01	330

42	1,2,4-Butanetriol	0.05	285
43	Pentaerythritol	0.01	347
44	Pentaerythritol	0.15	259
45	Ethylene Glycol	0.01	334
46	1,3-Propanediol	0.01	362
47	1,3-Propanediol	0.15	481
48	2,3-Butanediol	0.01	354
49	2,3-Butanediol	0.15	230

⁶ Average 4-Ball: 40kgf, 60°C, 1200 RPM, 60 Minutes

⁷ 60mM HOB Sulfonate, glycerol derivative (wt% stated), and Base Oil

[0066] As shown in Table 3, the Four-Ball Wear results of **Examples 39-49**, demonstrate the antiwear capability of glycerol and glycerol derivatives at low amounts (0.01-0.15 wt. %).

[0067] It will be understood that various modifications may be made to the embodiments disclosed herein. Therefore, the above description should not be construed as limiting, but merely as exemplifications of embodiments of the invention. For example, the functions described above and implemented for operating are for illustration purposes only. Other arrangements and methods may be implemented by those skilled in the art without departing from the scope and spirit of this application. Moreover, those

skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

CLAIMS

1. An electric driveline fluid comprising:
 - (a) a major amount of an oil of lubricating viscosity;
 - (b) an electric driveline additive comprising glycerol, glycol, glycol ether, pentaerythritol, vicinal diol, triol, or a derivative thereof; and
 - (c) at least one overbased sulfonate detergent;wherein the amount of the electric driveline additive is from about 0.001 wt. % to about 1.5 wt. % based on the total weight of the electric driveline fluid.
2. The electric driveline fluid of claim 1, wherein the at least one overbased sulfonate detergent is a high overbased calcium sulfonate.
3. The electric driveline fluid of claim 1, wherein the derivative thereof is a cyclic derivative.
4. The electric driveline fluid of claim 1, wherein the electric driveline fluid is substantially free of a sulfur-containing zinc compound.
5. The electric driveline fluid of claim 1, wherein the electric driveline fluid has less than 100 ppm of Zn.
6. The electric driveline fluid of claim 1, further comprising a derivative of glycerol that includes 2 or more vicinal diols.

7. The electric driveline fluid of claim 1, wherein the derivative thereof is a cyclic derivative having a 5- or 6-membered ring.
8. A method of improving the wear, friction, or fatigue performance of an engine featuring an electric driveline, the method comprising lubricating the engine with an electric driveline fluid comprising:
- (a) a major amount of an oil of lubricating viscosity;
 - (b) an electric driveline additive comprising glycerol, glycol, glycol ether, pentaerythritol, vicinal diol, triol, or a derivative thereof; and
 - (c) at least one overbased sulfonate detergent;
- wherein the amount of the electric driveline additive is from about 0.001 wt. % to about 1.5 wt. % based on the total weight of the electric driveline fluid.
9. The method of claim 8, wherein the at least one overbased sulfonate detergent is a high overbased calcium sulfonate.
10. The method of claim 8, wherein the derivative thereof is a cyclic derivative.
11. The method of claim 8, wherein the electric driveline fluid is substantially free of a sulfur-containing zinc compound.
12. The method of claim 8, wherein the electric driveline fluid has less than 100 ppm of Zn.

13. The method of claim 8, wherein the electric driveline fluid further comprises a derivative of glycerol that includes 2 or more vicinal diols.
14. The method of claim 8, wherein the derivative thereof is a cyclic derivative having a 5- or 6-membered ring.