

TITLE

USE OF ESTER BASE STOCKS TO IMPROVE VISCOSITY INDEX AND EFFICIENCY IN DRIVELINE AND INDUSTRIAL GEAR LUBRICATING FLUIDS

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BACKGROUND OF THE INVENTION

[0001] The disclosed technology relates to lubricants for driveline and industrial gears containing a mono-ester or a mixture of mono- and di-esters, as well as a method of lubricating driveline and industrial gears with such a lubricant.

[0002] Market demands are driving lubricating fluids towards lower viscosities in an effort to minimize energy losses due to mechanical operations. As fluids become less viscous, the base oil contribution to performance becomes increasingly more important. Performance attributes of base oils are highly dependent on the type of base oil chosen for a specific application. Mineral oils are derived from crude oil and therefore contain mixtures of aliphatic, cycloaliphatic and aromatic substances. Mineral oils have been categorized by the American Petroleum Industry (API) as Group I, Group II, or Group III based on their physical properties.

[0003] In contrast to mineral oils, synthetic oils contain molecules that are more consistent with respect to size and shape, the properties of which can be tuned by the selection of raw materials. Synthetic base oils are categorized by API as either Group IV or Group V oils. All polyalphaolefins (PAO) are considered to be Group IV base oils, while Group V covers any other synthetic base oil, such as mono and dibasic acid esters, polyol esters and alkylated aromatics.

[0004] Japanese patent application 2009023385A, filed by Tonengeneral Sekiyu Kk, teaches a method of reducing the traction coefficient for hydrocarbon-based synthetic oils, such as PAO, with a mono-ester. Similarly, US2018/0112148 published Apr. 26, 2018 to Bouvier et al. teaches a composition of a PAO and a mono-ester. Neither reference teaches or suggests that a mono-ester would provide any effect for a mineral oil based system, or that any particular result would occur with the combination of a mono-ester and di-ester. In fact, the Japanese reference expressly indicates that di-esters significantly increase traction coefficient.

[0005] U.S. 9,976,099 to Kit Ng et al., issued May 22, 2018, teaches the use of aromatic mono-esters to help improve traction control. The reference does not teach

or suggest the use of linear or branched mono-esters, nor the combination of mono-ester and di-ester.

[0006] US 9,540,587 issued to Nakao et al. Jan. 10, 2017 and US 10,227,541 issued to Masuda et al. Mar. 12, 2019 each teach a composition with improved viscometrics
5 containing, among other things, a mineral oil and a mono-ester. The reference says nothing of improving traction coefficient, nor the combination of mono-ester and di-ester.

[0007] The choice of which base oil to use for an application is often dependent on cost, availability, and desired performance characteristics. Group IV base oils, or poly
10 α -olefins, offer the most in terms of performance attributes, like traction. However, the cost and availability of high-end oils, like PAO, make them less than ideal. Enabling a lower treat rate of the Group IV oils, or the use of the more affordable and readily available group II and III type oils to provide improved low and high temperature traction, and/or improved viscosity index ("VI") performance would be an attractive alternative.
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SUMMARY OF THE INVENTION

[0008] The disclosed technology, therefore, solves the problem of reducing the overall treat of Grp IV base oils, and/or comparable performance between group II and/or III type oils and Group IV base oils by combining group II and/or III type oils
20 with a mono-ester or mixture of mono-ester and di-ester.

[0009] It was found that supplementing group IV base oils with a percentage of a mono-ester made it possible to realize the benefit of the ester on performance characteristics, such as traction and friction, while reducing the treat rate of the group IV base oil. It was further discovered that the mono-esters made it possible to realize
25 the benefit of the ester on performance characteristics, such as traction, while maintaining the majority of the base fluid as a low cost/ low viscosity Group II and/or III oil. These discoveries were surprising and unexpected as the majority of accepted wisdom would direct those of ordinary skill in the art to employ more complex esters.

[0010] Thus, one aspect of the technology disclosed herein is directed to a lubricant composition containing a) a hydrocarbon lubricating base stock, and b) from
30 about 1 or 1.5 to about 15 wt.% of a carboxylic acid mono-ester, such as, for example, ethylhexyl laurate. In certain embodiments, the hydrocarbon lubricating base stock

can be a Group IV base oil, such as a PAO. In some embodiments, the hydrocarbon lubricating base stock can be a Group II base oil. In embodiments, the hydrocarbon lubricating base stock can be a Group III base oil. In embodiments, the hydrocarbon lubricating base stock can be a mixture of two or more of a PAO, Group II, and Group III base oil.

[0011] It was also found that supplementing group II and/or Group III base oils with a combination of mono-esters and di-esters provided a synergistic result on traction over a broad range of operating temperatures, while maintaining the majority of the base fluid as a low cost/ low viscosity Group II and/or Group III oil.

[0012] Thus, another aspect of the disclosed technology provides a lubricant composition containing a) a hydrocarbon lubricating base stock, b) from about 1 or 1.5 to about 10 wt.% of a carboxylic acid mono-ester, such as, for example, ethylhexyl laurate, and c) from about 1 or 1.5 to about 10 wt.% of a dicarboxylic acid di-ester, such as, for example di-isooctyl adipate.

[0013] For example, the technology encompasses a lubricant composition containing an American Petroleum Institute ("API") Group II, III or IV lubricating oil along with at least one of a lauric acid mono-ester, tallow acid mono-ester, oleic acid mono-ester, palmitic acid mono ester, and combinations thereof, as well as at least one of an adipic acid diester, azelaic acid diester, and combinations thereof.

[0014] The technology also provides a method of lubricating a driveline device or an industrial gear with a composition as described, and operating the driveline device or industrial gear.

DETAILED DESCRIPTION OF THE INVENTION

[0015] Various preferred features and embodiments will be described below by way of non-limiting illustration.

[0016] The technology includes a lubricant composition containing a hydrocarbon lubricating base stock, and a combination of esters, namely, a carboxylic acid mono-ester and a dicarboxylic acid di-ester.

Hydrocarbon Lubricating Base Stock

[0017] One component of the disclosed technology is a hydrocarbon lubricating base stock. Such oils include natural and synthetic oils, oil derived from

hydrocracking, hydrogenation, and hydrofinishing, unrefined, refined and re-refined oils and mixtures thereof.

[0018] Unrefined oils are those obtained directly from a natural or synthetic source generally without (or with little) further purification treatment. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Purification techniques are known in the art and include solvent extraction, secondary distillation, acid or base extraction, filtration, percolation and the like. Re-refined oils are also known as re-claimed or reprocessed oils, and are obtained by processes similar to those used to obtain refined oils and often are additionally processed by techniques directed to removal of spent additives and oil breakdown products.

[0019] Natural oils useful in making the inventive lubricants include mineral lubricating oils such as liquid petroleum oils and solvent-treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types and oils derived from coal or shale or mixtures thereof.

[0020] Synthetic hydrocarbon lubricating oils suitable for use include Group IV oils or polyalpha olefins (PAO). Group IV oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers); poly(1-hexenes), poly(1-octenes), poly(1-decenes), and mixtures thereof.

[0021] Oils of lubricating viscosity may also be defined as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines (2011). The base oil groups suitable for use include Group II, Group III or Group IV oils. Group II and Group III oils have a sulfur content ≤ 0.03 wt %, and ≥ 90 wt % saturates. Group II oils have a viscosity index 80 to less than 120, while Group III oils have a viscosity index ≥ 120 . Group IV oils include all polyalphaolefins (PAOs).

[0022] The hydrocarbon lubricating base stock may be an API Group IV oil, or mixtures thereof, i.e., a polyalphaolefin. The polyalphaolefin may be prepared by metallocene catalyzed processes or from a non-metallocene process.

[0023] The hydrocarbon lubricating base stock may comprise an API Group II oil, or mixtures thereof. The hydrocarbon lubricating base stock can also be a Group III

oil, or mixtures thereof. The hydrocarbon lubricating base stock can also be a Group IV oil, or mixtures thereof.

[0024] The hydrocarbon lubricating base stock, or base oil, will overall have a kinematic viscosity at 100 °C of 2 to 10 cSt or, in some embodiments 2.25 to 9 or 2.5 to 6 or 7 or 8 cSt, as measured by ASTM D445. Kinematic viscosities for the base oil at 100 °C or from about 3.5 to 6 or from 6 to 8 cSt are also suitable.

[0025] The amount of the hydrocarbon lubricating base stock present is typically the balance remaining after subtracting from 100 wt % the sum of the amount of the performance additives in the composition. Illustrative amounts may include 50 to 99 percent by weight, or 60 to 98, or 70 to 95, or 80 to 94, or 85 to 93 percent.

Ester Base Stock

[0026] The lubricating composition will also include at least one carboxylic acid mono-ester, or a combination of a carboxylic acid mono-ester and a dicarboxylic acid di-ester.

[0027] The carboxylic acid-mono-ester is a molecule having a formula $RC(O)OR'$, where $RC(O)O-$ represents the carboxylic acid moiety and R' represents the ester group.

[0028] The R group of the carboxylic acid moiety, $RC(O)O-$, of the carboxylic acid mono-ester can be a C_2 to C_{18} linear or branched hydrocarbyl group. In some embodiments, the R group of the carboxylic acid moiety of the carboxylic acid mono-ester can be a C_4 to C_{15} , or a C_6 to C_{12} linear or branched hydrocarbyl group. The hydrocarbyl group can, in some embodiments, include heteroatoms, but in many instances the hydrocarbyl group will be an alkyl group. Thus, in some embodiments, the R group of the carboxylic acid moiety of the carboxylic acid mono-ester can be a C_2 to C_{18} , C_4 to C_{15} , or a C_6 to C_{12} linear or branched alkyl group.

[0029] Carboxylic acids from which the $RC(O)O-$ moiety may be derived include, but are not limited to, for example, lauric acid, tallow acid, oleic acid, palmitic acid, and the like. Thus, the carboxylic acid mono-ester may be, for example, a lauric acid mono-ester, tallow acid mono-ester, oleic acid mono-ester, palmitic acid mono ester, and combinations thereof.

[0030] The ester moiety, R' , of the carboxylic acid mono-ester can be C_6 to C_{12} linear or branched alkyl moiety. Alkyl moieties envisaged include, but are not limited

to, for example, a hexyl moiety, ethylhexyl moiety, methylpentane moiety, ethylpentane moiety, dimethylhexane moiety, ethylmethylhexane moiety and the like.

[0031] In an embodiment, the carboxylic acid mono-ester may be, for example, 2-ethylhexyl tallate, 2-ethylhexyl oleate, 2-ethylhexyl laurate, 2-ethylhexyl palmitate, and combinations thereof.

[0032] The carboxylic acid mono-ester may be present in the lubricant composition at from about 1 or 1.5 to about 15 wt.%, or from about 2 to about 12.5, or about 10 to about 15 wt.%, or even from about 3 to about 10 wt.% or about 4 to 8 wt.%.

[0033] The dicarboxylic acid-di-ester is a molecule having a formula $R'O(O)CRC(O)OR'$, where $-O(O)CRC(O)O-$ represents the dicarboxylic acid moiety and R' represents the ester group.

[0034] The R group of the dicarboxylic acid moiety, $-O(O)CRC(O)O-$, of the dicarboxylic acid di-ester can be a C_3 to C_{12} or C_6 to C_{12} linear or branched hydrocarbyl group. The hydrocarbyl group can, in some embodiments, include heteroatoms, but in many instances the hydrocarbyl group will be an alkyl group. Thus, in some embodiments, the R group of the carboxylic acid moiety of the carboxylic acid mono-ester can be a C_3 to C_{12} , or a C_6 to C_{12} linear or branched alkyl group.

[0035] Dicarboxylic acid from which the $-O(O)CRC(O)O-$ moiety may be derived include, but are not limited to, for example, glutaric acid, adipic acid, azelaic acid, sebacic acid, and the like. Thus, the dicarboxylic acid di-ester may be, for example, a glutaric acid di-ester, adipic acid di-ester, azelaic acid di-ester, sebacic acid di-ester, and combinations thereof.

[0036] The ester moiety, R' , of the dicarboxylic acid di-ester can be C_6 to C_{12} linear or branched alkyl moiety. Alkyl moieties envisaged include, but are not limited to, for example, a hexyl moiety, ethylhexyl moiety, methylpentane moiety, ethylpentane moiety, dimethylhexane moiety, ethylmethylhexane moiety and the like.

[0037] In an embodiment, the dicarboxylic acid di-ester may be, for example, di-2-ethylhexyl azelate, di-isotridecyl adipate, di-isooctyl adipate, and combinations thereof.

[0038] The dicarboxylic acid di-ester may be present in the lubricant composition at from about 1 or 1.5 to about 15 wt.%, or from about 2 to about 12.5, or about 10 to about 15 wt.%, or even from about 3 to about 10 wt.%. or about 4 to 8 wt.%.

Other Additives

5 [0039] The lubricant composition can be employed in either driveline applications or in industrial gear applications. As a driveline lubricant, the lubricant composition can contain other additives typically used in driveline applications, including, for example, detergents, dispersants, friction modifiers, antiwear agents, corrosion inhibitors, viscosity modifiers, anti-oxidants, oil-soluble titanium compounds, metal al-
10 kylthiophosphate, organo-sulfides, including polysulfides, such as sulfurized olefins, thiadiazoles and thiadiazole adducts such as post treated dispersants.

[0040] The organo-sulfide can be present in a range of 0 wt % to 6 wt %, 4 wt % to 6 wt %, 0.5 wt % to 3 wt %, 3 wt % to 5 wt %, 0 wt % to 1 wt %, or 0.1 wt % to 0.5 wt % of the lubricating composition.

15 [0041] The organosulfide may alternatively be a polysulfide. In one embodiment at least about 50 wt % of the polysulfide molecules are a mixture of tri- or tetra-sulfides. In other embodiments at least about 55 wt %, or at least about 60 wt % of the polysulfide molecules are a mixture of tri- or tetra-sulfides. The polysulfides include sulfurized organic polysulfides from oils, fatty acids or ester, olefins or poly-
20 olefins.

[0042] Oils which may be sulfurized include natural or synthetic oils such as mineral oils, lard oil, carboxylate esters derived from aliphatic alcohols and fatty acids or aliphatic carboxylic acids (e.g., myristyl oleate and oleyl oleate), and synthetic unsaturated esters or glycerides.

25 [0043] Fatty acids include those that contain 8 to 30, or 12 to 24 carbon atoms. Examples of fatty acids include oleic, linoleic, linolenic, and tall oil. Sulfurized fatty acid esters prepared from mixed unsaturated fatty acid esters such as are obtained from animal fats and vegetable oils, including tall oil, linseed oil, soybean oil, rapeseed oil, and fish oil.

30 [0044] The polysulfide may also be derived from an olefin derived from a wide range of alkenes, typically having one or more double bonds. The olefins in one embodiment contain 3 to 30 carbon atoms. In other embodiments, olefins contain 3 to

16, or 3 to 9 carbon atoms. In one embodiment the sulfurized olefin includes an olefin derived from propylene, isobutylene, pentene, or mixtures thereof. In one embodiment the polysulfide comprises a polyolefin derived from polymerizing, by known techniques, an olefin as described above. In one embodiment the polysulfide includes

5 dibutyl tetrasulfide, sulfurized methyl ester of oleic acid, sulfurized alkylphenol, sulfurized dipentene, sulfurized dicyclopentadiene, sulfurized terpene, and sulfurized Diels-Alder adducts; phosphosulfurized hydrocarbons.

[0045] Examples of a thiadiazole include 2,5-dimercapto-1,3,4-thiadiazole, or oligomers thereof, a hydrocarbyl-substituted 2,5-dimercapto-1,3,4-thiadiazole, a hydrocarbylthio-substituted 2,5-dimercapto-1,3,4-thiadiazole, or oligomers thereof.

10 The oligomers of hydrocarbyl-substituted 2,5-dimercapto-1,3,4-thiadiazole typically form by forming a sulfur-sulfur bond between 2,5-dimercapto-1,3,4-thiadiazole units to form oligomers of two or more of said thiadiazole units. Further examples of thiadiazole compounds are found in WO 2008,094759, paragraphs 0088 through 0090.

[0046] In an embodiment, the lubricant composition can have a total sulfur level from all additives (i.e., not including base oil) of about 0.5 or 0.6 to about 3 wt.%, or from about 0.5 or 0.6 to about 2 wt.%. In another embodiment, the lubricant composition can have a total sulfur level from all additives (i.e., not including base oil) of about 0.2 to about 0.75 wt%, or from about 0.25 to about 0.5 wt.%.

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[0047] In an embodiment, the lubricant composition can be substantially free, or free of sulfurized olefin.

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[0048] The lubricant composition can also have a total phosphorus level of about 0.03 to about 0.5 wt.%, or 0.03 to about 0.35 wt.%, or even about 0.05 to about 0.3 wt.%, or about 0.08 to about 0.2 wt.%, or about 0.13 to about 0.2 wt.%, or about

25 0.1 to about 0.25 wt.%. The phosphorus can be brought to the lubricant composition, for example, from the amine-containing phosphorus antiwear agents discussed above, or other phosphorus containing compounds.

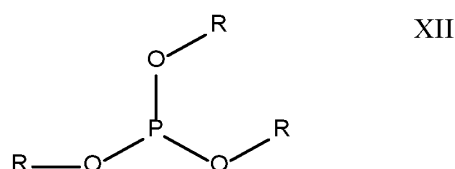
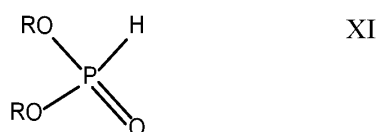
[0049] Other phosphorus-containing compounds may be included along with the amine-containing phosphorus antiwear agents. Such other phosphorus containing compounds can include phosphites or phosphonates. Suitable phosphites or phosphonates include those having at least one hydrocarbyl group with 3 or 4 or more, or

30 8 or more, or 12 or more, carbon atoms. The phosphite may be a mono-hydrocarbyl

substituted phosphite, a di-hydrocarbyl substituted phosphite, or a tri-hydrocarbyl substituted phosphite. The phosphonate may be a mono-hydrocarbyl substituted phosphonate, a di-hydrocarbyl substituted phosphonate, or a tri-hydrocarbyl substituted phosphonate.

5 [0050] In one embodiment the phosphite is sulphur-free i.e., the phosphite is not a thiophosphite.

[0051] The phosphite or phosphonate may be represented by the formulae:



wherein at least one R may be a hydrocarbyl group containing at least 3 carbon atoms
10 and the other R groups may be hydrogen. In one embodiment, two of the R groups are hydrocarbyl groups, and the third is hydrogen. In one embodiment every R group is a hydrocarbyl group, i.e., the phosphite is a tri-hydrocarbyl substituted phosphite. The hydrocarbyl groups may be alkyl, cycloalkyl, aryl, acyclic or mixtures thereof.

[0052] In the art, a phosphonate (i.e., formula XI with R = hydrocarbyl) may also
15 be referred to as a phosphite ester. Where one of the R groups in formula XII is an H group, the compound would generally be considered a phosphite, but such a compound can often exist in between the tautomers of formula XI and XII, and thus, could also be referred to as a phosphonate or phosphite ester. For ease of reference, the term phosphite, as used herein, will be considered to encompass both phosphites and
20 phosphonates.

[0053] The R hydrocarbyl groups may be linear or branched, typically linear, and saturated or unsaturated, typically saturated.

[0054] In one embodiment, the other phosphorus-containing compound can be a C₃₋₈ hydrocarbyl phosphite, or mixtures thereof, i.e., wherein each R may inde-
25 pendently be hydrogen or a hydrocarbyl group having 3 to 8, or 4 to 6 carbon atoms,

typically 4 carbon atoms. Typically the C₃₋₈ hydrocarbyl phosphite comprises dibutyl phosphite. The C₃₋₈ hydrocarbyl phosphite may deliver at least 175 ppm, or at least 200 ppm of the total amount of phosphorus delivered by the phosphorus-containing compounds. The C₃₋₈ hydrocarbyl phosphite may deliver at least 25wt.%, 35 wt.%,
5 45 wt.%, or 50 wt.% to 80 wt.%, or 50 wt.% to 75 wt.% or 60 wt.% to 70 wt.% of the total amount of phosphorus to the lubricant composition.

[0055] In one embodiment, the phosphorus-containing compound can be a C₁₂₋₂₂ hydrocarbyl phosphite, or mixtures thereof, i.e., wherein each R may independently be hydrogen or a hydrocarbyl group having 12 to 24, or 14 to 20 carbon atoms, typi-
10 cally 16 to 18 carbon atoms. Typically the C₁₂₋₂₂ hydrocarbyl phosphite comprises a C₁₆₋₁₈ hydrocarbyl phosphite. Examples of alkyl groups for R³, R⁴ and R⁵ include octyl, 2-ethylhexyl, nonyl, decyl, undecyl, dodecyl, tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl, octadecenyl, nonadecyl, eicosyl or mixtures thereof. The C₁₂₋₂₂ hydrocarbyl phosphite may be present in the lubricant composi-
15 tion at about 0.05 wt.% to about 4.0 wt.% of the lubricant composition, or from about 0.05 wt.% to about 3 wt.%, or from about 0.05 wt.% to about 1.5 wt.%, or from about 0.05 wt.% to about 1 wt.%, or from about 0.1 wt.% to about 0.5 wt.% of the lubricant composition.

[0056] In some embodiments, the other phosphorus containing compound can include both a C₃₋₈ and a C₁₂ to C₂₄ hydrocarbyl phosphite.
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[0057] In one embodiment, the phosphite ester comprises the reaction product of (a) a monomeric phosphoric acid or an ester thereof with (b) at least two alkylene diols; a first alkylene diol (i) having two hydroxy groups in a 1,4 or 1,5 or 1,6 relationship; and a second alkylene diol(ii) being an alkyl-substitute 1,3-propylene glycol.
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[0058] Sulfur containing phosphites can include, for example, a material represented by the formula $[R^1O(OR^2)(S)PSC_2H_4(C)(O)OR^4O]_nP(OR^5)_{2-n}(O)H$, wherein R¹ and R² are each independently hydrocarbyl groups of 3 to 12 carbon atoms, or 6 to 8 carbon atoms, or wherein R¹ and R² together with the adjacent O and P atoms form a
30 ring containing 2 to 6 carbon atoms; R⁴ is an alkylene group of 2 to 6 carbon atoms or 2 to 4 carbon atoms; R⁵ is hydrogen or a hydrocarbyl group of 1 to about 12 carbon atoms; and n is 1 or 2. The C₁₂₋₂₂ hydrocarbyl phosphite may be present in the

lubricant composition at about 0.05 wt.% to about 1.5 wt.% of the lubricant composition, or from about 0.1 wt.% to about 1.0 wt.% of the lubricant composition.

[0059] In one embodiment, the other phosphorus containing compound can be a phosphorus containing amide. Phosphorus containing amides can be prepared by reaction of dithiophosphoric acid with an unsaturated amide. Examples of unsaturated amides include acrylamide, N,N'-methylene bisacrylamide, methacrylamide, crotonamide and the like. The reaction product of the phosphorus acid and the unsaturated amide may be further reacted with a linking or a coupling compound, such as formaldehyde or paraformaldehyde. The phosphorus containing amides are known in the art and are disclosed in U.S. Pat. Nos. 4,670,169, 4,770,807 and 4,876,374 which are incorporated by reference for their disclosures of phosphorus amides and their preparation.

[0060] Other materials may be present in the lubricant composition in their conventional amounts including, for example, viscosity modifiers, dispersants, pour point additives, extreme pressure agents, antifoams, copper anticorrosion agents (such as dimercaptiothiadiazole compounds), iron anticorrosion agents, friction modifiers, dyes, fragrances, optional detergents and antioxidants, and color stabilizers, for example.

[0061] In one embodiment the final lubricant composition can have a kinematic viscosity at 100°C by ASTM D445 of 3 to 7.5, or 3.25 to 7, or 3.5 to 6.5, or 3.75 to 6 mm²/s. In some embodiments, the lubricant composition can have a kinematic viscosity at 100 °C by ASTM D445 of 5.5 to 7, or 5 to 6.5, or 5 to 6 mm²/s.

[0062] As a lubricant for industrial gears, the lubricant composition can contain other additives typically used in industrial gear applications, including, for example, foam inhibitors, demulsifiers, pour point depressants, antioxidants, dispersants, metal deactivators (such as a copper deactivator), antiwear agents, extreme pressure agents, viscosity modifiers, or some mixture thereof. The additives may each be present in the range from 50, 75, 100 or even 150 ppm up to 5, 4, 3, 2 or even 1.5 percent by weight, or from 75 ppm to 0.5 percent by weight, from 100 ppm to 0.4 percent by weight, or from 150 ppm to 0.3 percent by weight, where the percent by weight values are with regards to the overall lubricant composition. In other embodiments the other industrial additives, as a total additive package, can be present from 1 to 20, or from

1 to 10 percent by weight of the overall lubricant composition. However, it is noted that some additives, including viscosity modifying polymers, which may alternatively be considered as part of the base fluid, may be present in higher amounts including up to 30, 40, or even 50% by weight when considered separate from the base fluid. The additives may be used alone or as mixtures thereof.

[0063] In some embodiments the industrial lubricant additive packages, or the resulting industrial lubricant compositions, include a demulsifier, a corrosion inhibitor, a friction modifier, or combination of two or more thereof. In some embodiments the corrosion inhibitor includes a tolyltriazole. In still other embodiments the industrial additive packages, or the resulting industrial lubricant compositions, include one or more sulfurized olefins or polysulfides; one or more phosphorus amine salts; one or more thiophosphate esters, one or more thiadiazoles, tolyltriazoles, polyethers, and/or alkenyl amines; one or more ester copolymers; one or more carboxylic esters; one or more succinimide dispersants, or any combination thereof.

[0064] The disclosed technology provides a method of lubricating a driveline device, such as an automotive gear, axle or transmission, comprising supplying thereto a lubricating composition as described herein, that is, either a lubricating composition having (a) a hydrocarbon lubricating base stock, and (b) a carboxylic acid mono-ester, or a lubricating composition having (a) a hydrocarbon lubricating base stock, (b) a carboxylic acid mono-ester, and (c) a di-carboxylic di-ester, and operating the driveline device. In an embodiment, the lubricant composition disclosed herein can be employed to improve the traction coefficient of the lubricated gear at temperatures below 100°C.

[0065] The automotive gear may comprise a gear as in a gearbox of a vehicle (e.g., a manual transmission) or in an axle or differential, or in other driveline power transmitting driveline devices. The automotive gear may also include bearings. Lubricated gears may include hypoid gears, such as those for example in a rear drive axle.

[0066] The disclosed technology also provides a method of lubricating an industrial gear comprising supplying thereto a lubricating composition as described herein, that is, either a lubricating composition having (a) a hydrocarbon lubricating base stock, and (b) a carboxylic acid mono-ester, or a lubricating composition having

(a) a hydrocarbon lubricating base stock, (b) a carboxylic acid mono-ester, and (c) a di-carboxylic di-ester, and operating the driveline device. In an embodiment, the lubricant composition disclosed herein can be employed to improve the traction coefficient of the lubricated gear at temperatures below 100°C.

5 **[0067]** The amount of each chemical component described is presented exclusive of any solvent or diluent oil, which may be customarily present in the commercial material, that is, on an active chemical basis, unless otherwise indicated. However, unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial grade material which may contain the isomers, by-products, derivatives, and other such materials which are normally understood to be present
10 in the commercial grade.

[0068] As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group having a carbon atom directly attached to the remainder of
15 the molecule and having predominantly hydrocarbon character. Examples of hydrocarbyl groups include:

- hydrocarbon substituents, that is, aliphatic (e.g., alkyl or alkenyl), alicyclic (e.g., cycloalkyl, cycloalkenyl) substituents, and aromatic-, aliphatic-, and alicyclic-substituted aromatic substituents, as well as cyclic substituents wherein the ring is
20 completed through another portion of the molecule (e.g., two substituents together form a ring);
- substituted hydrocarbon substituents, that is, substituents containing non-hydrocarbon groups which, in the context of this invention, do not alter the predominantly hydrocarbon nature of the substituent (e.g., halo (especially chloro and fluoro), hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulfoxy);
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- hetero substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this invention, contain other than carbon in a ring or chain otherwise composed of carbon atoms and encompass substituents as pyridyl, furyl, thienyl and imidazolyl. Heteroatoms include sulfur, oxygen, and
30 nitrogen. In general, no more than two, or no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group;

alternatively, there may be no non-hydrocarbon substituents in the hydrocarbyl group.

[0069] It is known that some of the materials described above may interact in the final formulation, so that the components of the final formulation may be different from those that are initially added. For instance, metal ions (of, e.g., a detergent) can migrate to other acidic or anionic sites of other molecules. The products formed thereby, including the products formed upon employing the composition of the present invention in its intended use, may not be susceptible of easy description. Nevertheless, all such modifications and reaction products are included within the scope of the present invention; the present invention encompasses the composition prepared by admixing the components described above.

[0070] As used herein, the term "about" means that a value of a given quantity is within $\pm 20\%$ of the stated value. In other embodiments, the value is within $\pm 15\%$ of the stated value. In other embodiments, the value is within $\pm 10\%$ of the stated value. In other embodiments, the value is within $\pm 5\%$ of the stated value. In other embodiments, the value is within $\pm 2.5\%$ of the stated value. In other embodiments, the value is within $\pm 1\%$ of the stated value.

[0071] The invention herein is useful for fully formulated gear oils or industrial gear oils, which may be better understood with reference to the following examples.

[0072] EXAMPLES

[0073] Table 1 below is a list of esters that were studied. Esters 1-4 are monoesters (designated as ME), esters 5-9 are diesters (designated as DE), ester 10 is a tri ester (designated TE) and esters 11-13 are polyol esters (designated PE).

Table 1. Ester identities

Designation	Alcohol	Acid
ME-1	2-ethylhexanol	lauric
ME-2	2-ethylhexanol	Palmitic
ME-3	2-ethylhexanol	Tallow fatty
ME-4	2-ethylhexanol	Oleic
DE-5	2-ethylhexanol	Azelaic
DE-6	Isooctanol	Adipic
DE-7	Isotridecanol	Adipic
DE-8	Isofal 2426S	Adipic
DE-9	Isofal 2426S	Succinic

TE-10	Isodecyl	Trimellitic
PE-11	2-ethylhexanol	Dimerized fatty
PE-12	Trimethylol propane	C8-C10
PE-13	pentaerityrytol	unknown

[0074] Selected esters were combined with an additive package, a pour point depressant, a viscosity modifier and additional base oil. The additive package was identical in all samples and contained substituted thiadiazole, alkaryl amine, phosphorus amine salt, detergent, succinimide dispersant, alkylphenyl ether and polydimethylsiloxane. Samples 1-8 and 23 were blended using Group III mineral oil and contained a methacrylate copolymer as viscosity modifier. These samples contained Yubase 3/Yubase 6 in the ratio of 60/40wt. Samples 9-11 and 24 were blended using Group II mineral oil and contained an olefin copolymer as viscosity modifier. Samples 12-22 were blended using PAO and contained an olefin copolymer viscosity modifier. The amount of viscosity modifier was varied in order to target fluids with KV 100 at ~5.5 cSt. All samples were analyzed using a standard mini-traction machine (MTM) with a frictional force of 1.0 GPa pressure applied. In one set of conditions measurements were recorded at six different temperatures over a range of slide to roll ratios from 0.025 – 100. A second set of testing was completed at the same six temperatures over a range of speeds from 1-3000mm/s. Selected traction coefficient (“TC”) data is reported in the tables below.

Table 2. Formulations with Grp III mineral oil and methacrylate copolymer

Sample	Ester	TC @ 40°C 20% SRR	TC @ 140°C 20% SRR
Sample 1	None	0.0414	0.0077
Sample 2	ME-1	0.0374	0.0096
Sample 3	ME-2	0.0372	0.0074
Sample 4	ME-3	0.0380	0.0083
Sample 5	ME-4	0.0374	0.0069
Sample 6	DE-5	0.0391	0.0069
Sample 7	DE-6	0.0401	0.0068
Sample 8	TE-10	0.0450	0.0090

Table 3. Formulations with Grp II mineral oil and olefin copolymer

	Ester	TC @ 40°C 20% SRR	TC @ 140°C 20% SRR
Sample 9	None	0.0515	0.0120
Sample 10	ME-1	0.0455	0.0109
Sample 11	DE-6	0.0488	0.0102

Table 4. Formulations with PAO and olefin copolymer

	Ester	TC @ 40°C 20% SRR	TC @ 140°C 20% SRR
Sample 12	No ester	0.0270	0.0051
Sample 13	ME-1	0.0250	0.0040
Sample 14	ME-2	0.0250	0.0045
Sample 15	ME-3	0.0260	0.0062
Sample 16	DE-5	0.0260	0.0050
Sample 17	DE-7	0.0290	0.0047
Sample 18	DE-8	0.0282	0.0046
Sample 19	DE-9	0.0278	0.0047
Sample 20	PE-11	0.0280	0.0057
Sample 21	PE-12	0.0266	0.0045
Sample 22	PE-13	0.0280	0.0090

5 [0075] Tables 2-4 include traction coefficient data at both the lowest and highest temperatures tested at a 20% SRR. Surprisingly, in each of the three different types of base stocks, formulations containing the mono-esters gave the lowest traction coefficients compared to formulations containing di-esters, tri-esters or polyol esters at 40°C. In Grp II and Grp III base stocks, formulations containing diesters had the lowest traction coefficients at 140°C.

10 [0076] Further MTM experiments were conducted with Samples 23 and 24. These samples contained a 50/50 mixture of mono-ester ME-1 and diester DE-6. Sample 23 contained Grp III base oil and a polymethacrylate viscosity modifier. Traction coefficient data for Sample 23 can be compared to Sample 1 with no ester and Samples 2 and 7, which contain only a single ester. Tables 5 and 6 list traction coefficient data recorded as speed was varied from 10-3000 mm/s for selected speeds of 50 mm/s (Table 5) and 500mm/s (Table 6). Table 7 lists traction coefficient data recorded as the slide to roll ratio was varied from 0.025-100. Data in Table 7 was obtained when SRR = 50.

Table 5. Grp III formulations. Mean speed = 50 mm/s

	Sample 1	Sample 2	Sample 7	Sample 23
KV100	5.559	5.469	5.489	5.247
VI	153	167	162	160
Ester	None	ME-1	DE-6	ME-1/DE-6
40°C	0.0533	0.0512	0.057	0.0499
60°C	0.0519	0.0512	0.0538	0.0476
80°C	0.0528	0.0527	0.0573	0.0481
100°C	0.0544	0.0575	0.0621	0.0489
120°C	0.0578	0.0634	0.0682	0.0576
140°C	0.0649	0.0701	0.0751	0.0645

Table 6. Grp III formulations. Mean speed = 500 mm/s

	Sample 1	Sample 2	Sample 7	Sample 23
Ester	None	ME-1	DE-6	ME-1/DE-6
40°C	0.0473	0.0429	0.0461	0.0441
60°C	0.0384	0.0344	0.0374	0.0352
80°C	0.0310	0.0277	0.0310	0.0282
100°C	0.0257	0.0231	0.0268	0.0229
120°C	0.0224	0.0206	0.0246	0.0204
140°C	0.0220	0.0209	0.0243	0.0202

5 Table 7. Group III formulations. SRR=50.

	Sample 1	Sample 2	Sample 7	Sample 23
Ester	None	ME-1	DE-6	ME-1/DE-6
40°C	0.0414	0.0397	0.0403	0.0393
60°C	0.0355	0.0336	0.0341	0.0331
80°C	0.0290	0.0279	0.0276	0.0266
100°C	0.0232	0.0229	0.0218	0.0208
120°C	0.0184	0.0189	0.0172	0.0163
140°C	0.0147	0.0156	0.0135	0.0128

10 [0077] Generally, addition of the mono-ester lowered the traction coefficient over the range of temperatures where data was collected. Addition of the di-ester either increased the traction coefficient compared to the sample without ester, or it reduced the traction coefficient, but not to the same extent as the mono-ester. On average, when the mono- and di-ester were used in combination, the lowest traction coefficients were observed over the entire range of temperatures.

[0078] The synergy between the monoester, ME-1, and the diester, DE-6, was also observed for formulations containing Grp II diluent oil. Traction coefficient data for these formulations is shown in Tables 8-10. Sample 24 contains a 50/50 mixture of ME-1 and DE-6 in the presence of Grp II base oil.

5 Table 8. Grp II formulations. Mean speed = 50 mm/s

	Sample 9	Sample 10	Sample 11	Sample 24
KV100	5.510	5.502	5.487	5.52
VI	127	146	142	145
Ester	None	ME-1	DE-6	ME-1/DE-6
40°C	0.0650	0.0631	0.0652	0.0587
60°C	0.0611	0.0587	0.0648	0.0550
80°C	0.0616	0.0565	0.0687	0.0555
100°C	0.0598	0.0588	0.0637	0.0571
120°C	0.0689	0.0656	0.0722	0.0605
140°C	0.0757	0.0681	0.0788	0.0682

Table 9. Grp II formulations. Mean speed = 500 mm/s

	Sample 9	Sample 10	Sample 11	Sample 24
Ester	None	ME-1	DE-6	ME-1/DE-6
40°C	0.0589	0.0532	0.0566	0.0541
60°C	0.0501	0.0442	0.0472	0.0444
80°C	0.0420	0.0367	0.0394	0.0358
100°C	0.0356	0.0321	0.0339	0.0290
120°C	0.0322	0.0309	0.0318	0.0242
140°C	0.0329	0.0306	0.0319	0.0233

Table 10. Grp II formulations. SRR=50

	Sample 9	Sample 10	Sample 11	Sample 24
Ester	None	ME-1	DE-6	ME-1/DE-6
40°C	0.0508	0.0467	0.0489	0.0476
60°C	0.0453	0.0404	0.0425	0.0409
80°C	0.0383	0.0339	0.0352	0.0337
100°C	0.0312	0.0274	0.0283	0.0268
120°C	0.0250	0.0219	0.0224	0.0210
140°C	0.0197	0.0182	0.0174	0.0163

[0079] In addition to the synergy observed when a combination of ME-1 and DE-6 is used instead of a single ester, an additional synergy was observed with this combination when looking at the low temperature viscosity performance using the ASTM D2893 Brookfield viscosity test at -40°C.

5 Table 11. Grp III formulations. Brookfield Viscosity at -40°C

	Sample 1	Sample 2	Sample 7	Sample 23
	None	ME-1	DE-6	ME-1/DE-6
Brookfield viscosity at -40°C	8535	10336	8054	6105

[0080] Each of the documents referred to above is incorporated herein by reference, including any prior applications, whether or not specifically listed above, from which priority is claimed. The mention of any document is not an admission that such document qualifies as prior art or constitutes the general knowledge of the skilled person in any jurisdiction. Except in the Examples, or where otherwise explicitly indicated, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word "about." It is to be understood that the upper and lower amount, range, and ratio limits set forth herein may be independently combined. Similarly, the ranges and amounts for each element of the invention can be used together with ranges or amounts for any of the other elements.

[0081] As used herein, the transitional term "comprising," which is synonymous with "including," "containing," or "characterized by," is inclusive or open-ended and does not exclude additional, un-recited elements or method steps. However, in each recitation of "comprising" herein, it is intended that the term also encompass, as alternative embodiments, the phrases "consisting essentially of" and "consisting of," where "consisting of" excludes any element or step not specified and "consisting essentially of" permits the inclusion of additional un-recited elements or steps that do not materially affect the essential or basic and novel characteristics of the composition or method under consideration.

[0082] While certain representative embodiments and details have been shown for the purpose of illustrating the subject invention, it will be apparent to those skilled

in this art that various changes and modifications can be made therein without departing from the scope of the subject invention. In this regard, the scope of the invention is to be limited only by the following claims.

5 **[0083]** A lubricant composition comprising: a) a hydrocarbon lubricating base stock, b) from about 1 to about 15 wt.% of a carboxylic acid mono-ester.

[0084] The lubricant composition of the previous paragraph, wherein the carboxylic acid mono-ester comprises a C₈ to C₁₈ linear or branched carboxylic acid.

[0085] The lubricant composition of any previous paragraph, wherein the carboxylic acid mono-ester comprises a C₆ to C₁₂ linear or branched alkoxy group.

10 **[0086]** The lubricant composition of any previous paragraph, wherein the carboxylic acid mono-ester comprises a lauric acid mono-ester, tallow acid mono-ester, oleic acid mono-ester, palmitic acid mono ester, and combinations thereof.

[0087] The lubricant composition of any previous paragraph, wherein the carboxylic acid mono-ester comprises a 2-ethylhexyl alkoxy group.

15 **[0088]** The lubricant composition of any previous paragraph, wherein the carboxylic acid mono-ester comprises 2-ethylhexyl tallate.

[0089] The lubricant composition of any previous paragraph, wherein the carboxylic acid mono-ester comprises 2-ethylhexyl oleate.

20 **[0090]** The lubricant composition of any previous paragraph, wherein the carboxylic acid mono-ester comprises 2-ethylhexyl laurate.

[0091] The lubricant composition of any previous paragraph, wherein the carboxylic acid mono-ester comprises 2-ethylhexyl palmitate.

[0092] The lubricant composition of any previous paragraph, wherein the mono-ester is present at from about 1.5 to about 15 wt.%.

25 **[0093]** The lubricant composition of any previous paragraph, wherein the mono-ester is present at from about 2 to about 12.5 wt.%.

[0094] The lubricant composition of any previous paragraph, wherein the mono-ester is present at from about 3 to about 10 wt.%.

[0095] The lubricant composition of any previous paragraph, wherein the mono-ester is present at from about 4 to about 8 wt.%.

[0096] The lubricant composition of any previous paragraph, wherein the mono-ester is present at from about 10 to about 15 wt.%.

5 [0097] The lubricant composition of any previous paragraph, further comprising from about 1 to about 15 wt.% of a dicarboxylic acid di-ester.

[0098] The lubricant composition of any previous paragraph, wherein the dicarboxylic acid di-ester comprises a C₃ to C₁₂ linear or branched dicarboxylic acid.

10 [0099] The lubricant of any previous paragraph, where the dicarboxylic acid di-ester comprises adipic acid diester, azelaic acid diester, and combinations thereof.

[0100] The lubricant composition of any previous claim, wherein the dicarboxylic acid di-ester comprises di-2-ethylhexyl azelate.

[0101] The lubricant composition of any previous paragraph, wherein the dicarboxylic acid di-ester comprises diisotridecyl adipate.

15 [0102] The lubricant composition of any previous paragraph, wherein the dicarboxylic acid di-ester comprises diisooctyl adipate.

[0103] The lubricant composition of any previous paragraph, wherein the di-ester is present at from about 1.5 to about 15 wt.%.

20 [0104] The lubricant composition of any previous paragraph, wherein the di-ester is present at from about 2 to about 12.5 wt.%.

[0105] The lubricant composition of any previous paragraph, wherein the di-ester is present at from about 3 to about 10 wt.%.

[0106] The lubricant composition of any previous paragraph, wherein the di-ester is present at from about 4 to about 8 wt.%.

25 [0107] The lubricant composition of any previous paragraph, wherein the di-ester is present at from about 10 to about 15 wt.%.

[0108] The lubricant composition of any previous paragraph wherein the hydrocarbon lubricating base stock comprises an American Petroleum Institute ("API") Group IV polyalphaolefin.

[0109] The lubricant composition of any previous paragraph wherein the hydrocarbon lubricating base stock comprises an American Petroleum Institute (“API”) Group III oil mineral oil.

5 [0110] The lubricant composition of any previous paragraph wherein the hydrocarbon lubricating base stock comprises an American Petroleum Institute (“API”) Group II oil mineral oil.

[0111] A method of improving traction coefficient in a lubricated gear, comprising supplying to the gear a lubricant composition according to any previous paragraph.

10 [0112] The method of the previous paragraph, wherein the lubricant composition is provided at a temperature of less than 100°C.

[0113] The use of a mono-ester in a lubricant composition for a gear to improve traction coefficient.

15 [0114] The use according to the previous paragraph, wherein the use is at a temperature of less than 100°C.

[0115] The use of a combination of a mono-ester and di-ester in a lubricant composition for a gear to improve traction coefficient.